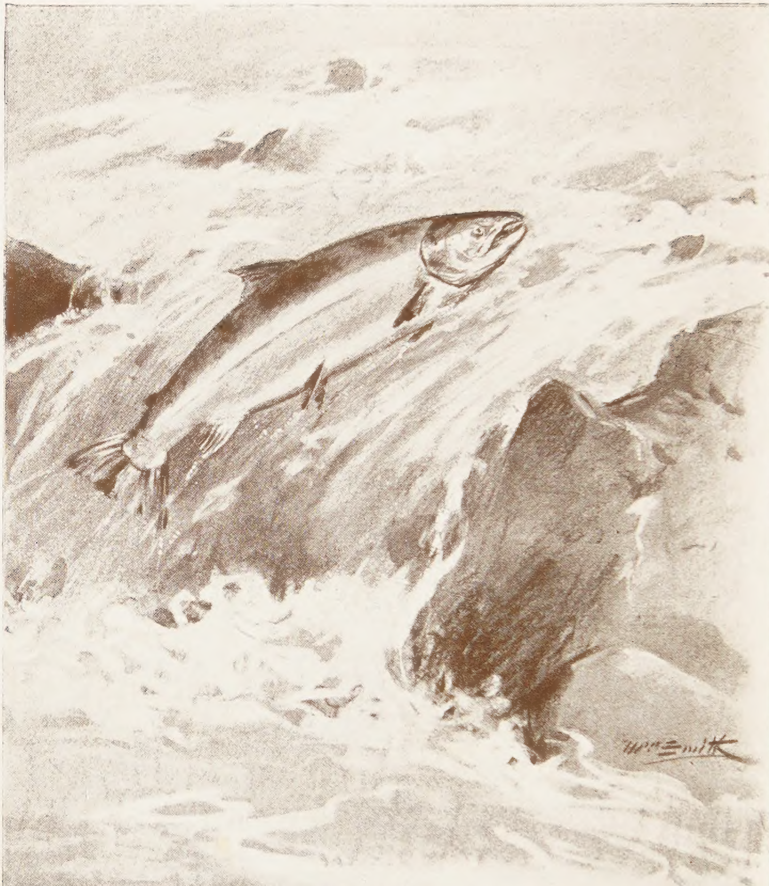
THE HAUNTS OF LIFE



SALMON ASCENDING A FALL.

Frontispiece]

THE HAUNTS OF LIFE

BY

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NEW YORK
HARCOURT, BRACE AND COMPANY

PRINTED IN THE U. S. A. BY
THE QUINN & BODEN COMPANY
RAHWAY, N. J.

THIS LITTLE BOOK

IS DEDICATED GRATEFULLY

TO A VETERAN NATURALIST

EMERITUS PROFESSOR W. C. M‘INTOSH

M.D., LL.D., F.R.S.

WHO HAS DEVOTED HIS LIFE

TO THE STUDY OF ANIMALS IN THEIR HAUNTS

PUBLISHERS' NOTE

OF the illustrations in this book twelve plates are by Mr. William Smith; the remainder are by Miss Alice M. Davidson.

PREFACE

THIS simple book consists of six lectures which I had the honour and pleasure of giving at the Royal Institution in the Christmas holidays, 1920–1921. The aim of these lectures was mainly to help my very alert audience to form vivid pictures of the great haunts of animal life, and to get glimpses of the subtle ways in which living creatures solve the problems of particular places. I have kept in the printed pages as closely as I could to what I said at the time, hoping to secure the virtue of simplicity. I think it would be very ungracious if I did not use the opportunity of this preface to thank Sir James Dewar, LL.D., D.Sc., F.R.S., for the great kindness that he showed me when I was for a delightful fortnight in the service of the Royal Institution.

J. A. T.

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THE HAUNTS OF LIFE

CHAPTER I

THE SCHOOL OF THE SHORE

The Shore of the Sea—In Deeper Waters near Shore—A Representative Population—A Difficult Place to Live in—The Struggle of the Shore—The Circulation of Matter—Cannibalism in the Cradle—Shore Seaweeds—Food-getting on the Shore—The Story of the Angler—The Star-fish and Sea-urchin Fight—Shifts for a Living on the Shore—Masking—A Limb for a Life—Colour Camouflage—Love on the Shore—The Story of Palolo—A Great School.

IT is interesting to watch a big river rising slowly in flood. The water overtops the banks and spreads foot by foot everywhere, filling every hollow, forgetting no corner. So is it with living creatures; they spread over all the earth. Life is like a river that is always overflowing its banks. There are no fishes in the Great Salt Lake of Utah, there are no birds swimming on its surface, yet there are brine-shrimps and two or three more living

creatures tenanting its dense waters. Little fresh-water snails may be seen creeping on the stones close to the brink of the Niagara Falls. An army of a million tiny wingless insects has been observed crossing the Mer de Glace near Chamonix. There are insects that run about on the surface of the Open Sea. There are many animals that find a home in coal-pits. It seems as if there are no corners which living creatures have not explored, from the great abysses of the Deep Sea, perhaps six miles below the surface, to near the summits of the Alps, from the floating iceberg in the North to beneath ten feet of ice on the Antarctic shore. Perhaps there are always some living creatures trying to conquer a new kingdom. Life is a kind of activity, and living creatures tend to be restless, seeking out places where they can express themselves and assert themselves more fully.

Thus it has come to pass that living creatures have spread over all the earth, and in the waters under the earth, and in more than the seven seas. One may almost say that over earth and sea life is omnipresent. But it is very useful to distinguish SIX GREAT HAUNTS OF LIFE:

I. The Shore of the Sea (Littoral).
II. The Open Sea (Pelagic).
III. The Depths of the Sea (Abyssal).
IV. The Fresh Waters (Fluviatile, Lacustrine, etc.).
V. The Dry Land (Terrestrial).
VI. The Air (Aërial).

THE SHORE OF THE SEA

By the shore-haunt or littoral region naturalists mean more than is suggested in ordinary conversation when we speak of the sea-shore. For then we mean the stretch between tide-marks, whereas the naturalist's shore-haunt is the whole of the comparatively shallow, well-lighted, seaweed-growing area round the margin of a continent, or of an island that was once part of a continent. There are places where there is practically no shore; for instance round an oceanic island that has been formed by corals growing on the shoulders of a submarine volcano. In such a place a stone thrown out from the land will drop—*kerblunkity blink*—into really deep water. And there are other places where the shore goes out and out for many miles; for

instance, where a fringing coral-reef extends far out to sea. The naturalist's shore-haunt is the whole of the seaweed-growing area, and we call it shore, although the water may be deep enough to float a navy.

The shore-haunt is not very large compared with other haunts. It occupies about nine million square miles, but that is only between six and seven per cent. of the sea-covered surface of the globe. It is a very *long* area, going in and out, by bay and creek, by firth and fiord, for about 150,000 miles. And it is a region of great diversity, differing from place to place according to the geological character of the shore, according to the mineral materials that the streams bring down from the land, and according to the jetsam that is thrown up from the sea. In some places the whole of the shore between tide-marks is covered with a thick mass of dead seaweed, which rots away and smells badly when the tide is out. There are crowds of tiny creatures—*e.g.* allies of sand-hoppers—working away among this decaying seaweed; but the ordinary life of the shore-pools has been smothered, and exploration in this kind of shore-haunt is rather an acquired taste. There are shores and shores.

Even if we keep to the shore in the narrower sense there is great variety of conditions. Take first the great masses of rock which often run far out to sea. Their tops and their seaward faces are exposed for the greater part of the day to the full violence of the wind and the heat of the sun; as the water rises the waves beat against them, and they are only completely submerged for a short time at very high tide. Yet even these have their inhabitants. Behind and between these weather-beaten masses there is shade and moisture; sheltered nooks and crannies abound; the smaller rocks at their bases are covered with sea-wrack, and every hollow contains a quiet pool of water left by the receding tide, each pool harbouring a crowded life.

Beside the rocks are the great stretches of flat, smooth sand where we have built castles and dug moats, and the sands, too, have their own particular population, though it is not always easy to see it. Sometimes instead of sand there is shingle, gravel, or even large pebbles smoothed or rounded by the action of the waves. This kind of shore is the most unfavourable of all to animal life. We shall easily find the reason for ourselves if we bathe

or wade among the surf on a pebbly shore, for on a rough day we may come out of the water tingling and bruised all over with the continually moving stones.

The mud flats formed at river-mouths by the soil carried down by the streams have their inhabitants too, as we can easily guess from the large numbers of birds that are busy feeding there at low tide.

Finally, there is the most populous part of the whole region, the stretch of flat rocks covered with the great seaweeds—from which the belt takes its name—"the laminarian zone." A part of this region is not uncovered except at very low tides.

IN DEEPER WATERS NEAR SHORE

In warm seas, beside a coral-reef for instance, naturalists have been able to work for hours at a depth of 10 to 15 feet. They simply put on a metal hood fitting the shoulders and connected with a compression-pump on the launch above by means of a long hose-pipe which allows complete freedom of movement. The diver breathes freely inside his hood, and the weight of it is greatly reduced in the

PLATE I.—CROWDED GROUP OF GUILLEMOTS, ON A STACK OF ROCK, FARNE ISLANDS.

Note also some Kittiwakes.

Photograph by NORRIE, Fraserburgh.

water. It is possible in this way to get very near the animals, and to watch their goings on.

Mr. W. H. Longley tells of his experiences beside a tropical coral-reef. "It is a strange world in which the diver finds himself; it is so small and still; so surrounded with mystery; so surprisingly unlike that which one imagines it to be, observing it from the surface. Even when the light is brightest, and the water most free from sediment, one never sees objects at a greater distance than a few yards (in one very favourable case, fifteen paces); and if a heavy surf is pounding a short distance seaward, so much débris may be borne inshore on a rising tide that one may be shut in almost as completely as in a blinding snowstorm, and have no means of finding one's way back to the boat other than following the hose. No sound reaches one save that of the air rushing into the hood at each stroke of the pump above. Graceful Gorgonians (*i.e.* Sea-fans; much branched, flexible, Alcyonarian corals), purple, brown, yellow, or olive, may sway gently as the lazy swell rolls overhead; or, as one clambers about the face of some submerged escarpment, one may see, from below, sheets of foam spreading where trampling rollers raised

by an incessant trade wind have broken. Yet all transpires in perfect silence." One feature that contributes to the strangeness of the surroundings is that all vertical distances prove to be much greater than they appear from the surface of the water. An apparently smooth floor turns out to be rough, and a rough one is found to be seamed by ragged crevasses.

Mr. Longley tells us of some of the sights he saw. A bit of food thrown on to the sandy floor would tempt crabs out of hiding; they would scuttle over the bottom like shadowy ghosts, so like are they to their surroundings; then they would scrape and scratch a little with their hind legs and go down backwards out of sight. Flounders, coloured and patterned just like the bottom, would rise and sink again, burying themselves in the drifting sand, all but their protruding watchful eyes. From a tiny hole in the coral a small fish "with an enormous dorsal fin would protrude half its body, and rapidly and repeatedly elevate and depress its great banner, while another seems to respond to the signal." "Often one observes incidents which remain incomprehensible, as when two yellow grunts (*Hæmulon sciurus*) approach one another

slowly, snout to snout, open their mouths to the limit of their gape, and gaze, as it seems, for several seconds, as if in rapt attention, each at the patch of bright red on the other's mouth."

A near view shows that there is haunt within haunt. There are sandy corners and seaweedy corners, sheltered coral basins and open reefs, shady places and illumined places, and all the different levels from the floor to the surface. Of course there are bold wanderers that go everywhere, but on the whole each creature has its favourite and habitual corner, to which it is particularly well suited, especially as regards its colour and patterns. And different creatures tenant the same place at different times: thus, when evening approaches, the day-feeding fishes disappear, and out of the recesses of the reef come night-feeding fishes, first in twos and threes, and then in schools. There are many "Box and Cox" arrangements in Nature.

The big result of close observation of the shore-haunt is to show that it includes a great variety of surroundings, and that many a creature has a particular niche where it is most at home.

A REPRESENTATIVE POPULATION

Of all the haunts of life, the shore has the most representative fauna or assemblage of animals. Almost every kind of creature is there. Let us begin at the top of the genealogical tree.

On some quiet British shores the seals come out of the water to rest, and are sometimes caught napping by men who have no mercy. They bring forth their young ones, usually one for each mother, in caves or in sheltered nooks among the rocks; and this tells us part of the secret of seals,—that they are the aquatic descendants of terrestrial mammals. For it is a general Natural History rule that animals go back to their old home to breed. What is seen on a small scale on British shores is seen magnified elsewhere; for instance in Alaska, where the fur-seals have their great rookeries.

On other British shores the otter has its home, or rather one of its homes, for otters are roving animals. They often swim several miles to reach an island off the coast; they can dive more than full fathoms five to catch the plaice lying on the sandy floor of the bay; when they are severely rationed they pick

PLATE II.—TERNS OR SEA-SWALLOWS, FLYING ON THE SHORE.

Note the very long wings and the forked tail. On the dunes three eggs may be seen in a little scraping on the sand.

about among the rocks, not disdaining limpets and mussels.

Besides seals and otters there are other mammals that frequent or may frequent the shore. The polar bear in the Arctic regions sometimes lies down beside an opening in the thick ice and waits for a seal to come up to breathe. With one stroke of its great arm it has been known to lift the seal right out of the water, and send it crashing over the ice instantaneously killed. The walruses, also of the North, dig up the bivalves with their huge tusks. Along warm coasts the dugongs and manatees, jointly known as sea-cows, browse on the seaweeds. But we have said enough: the shore-fauna includes mammals.

BIRDS.—There are many birds characteristic of the shore, especially at certain seasons. We think of gulls and terns, dunlins and sandpipers, curlew and whimbrel, shag and cormorant, and many others—a fine account of which will be found in Mr. W. P. Pycraft's delightful book *The Sea Shore.* We can only select a representative. The oyster-catcher is often to be seen where there are limpets and mussels in abundance. The black and white

plumage, the ruddy legs, the red and yellow bill, the shrill cry, the rapid flight, make it very conspicuous. It breaks a hole in one valve of the mussel's shell, and inserting its bill scoops out the palatable flesh. With a dexterous side-stroke of its strong bill it can jerk the limpet off the rock; but to do this, as everyone knows who has tried, it is necessary to take the mollusc unawares and to strike quickly.

REPTILES.—There is a marine lizard (*Amblyrhynchus*) on the Galapagos Islands that swims out to sea and dives after seaweed. There are sea-snakes that come ashore to bring forth their young. Crocodiles and alligators may be found on the shores of estuaries. The sea-turtles bury their eggs in the sand of sun-baked shores.

AMPHIBIANS.—There seems to be something about salt that is prejudicial to amphibians. Thus they are not found near the sea and are unrepresented on Oceanic Islands, where the tenants are restricted to those creatures that could survive being drifted on logs and the like, or could be carried by birds or the wind. But we are reminded of the dan-

ger of hard-and-fast statements by the fact that there is a frog at Manilla which is often seen hopping about on the shore.

FISHES.—The shore-fishes are legion, but some are more characteristic than others. One of these is the Gunnel or Butterfish (*Centronotus gunnellus*), so extraordinarily difficult to catch because of its power of insinuating itself between the stones and into crevices, so extraordinarily difficult to hold when one has caught it, such is its slipperiness. The father-lasher and the sand-eel, the cock-paidle and the stickleback are also common on the shore.

SEA-SQUIRTS.—Fastened to the long flag-like seaweeds there are often groups of Ascidians or Sea-Squirts, strange degenerate creatures which cross the frontier into the backboned sub-kingdom in their free-swimming youth, but sink back again, as it were, when they grow up and settle down. On the stones at low tide there are often very beautiful colonies of compound Ascidians or Tunicates, quite jewel-like sometimes in their fine colouring.

MOLLUSCS.—Highest in a way among backboneless or Invertebrate animals are the Mol-

luscs—the bivalves, snails, and cuttlefishes; and these—especially the first two classes—are well represented on the shore. Bivalves are represented by cockle and mussel, oyster and clam; snails by the vegetarian periwinkle and limpet, and the carnivorous dog-whelk and buckie; cuttlefish by an occasional octopus hunting for crabs among the low-tide rocks. Even Aristotle knew, over two thousand years ago, how a shore cuttle shoots out an arm and grapples a passing fish.

Fig. 1.—The King-Crab, Limulus. A very ancient Shore Arthropod.

Arthropods.—On quite a different line of life from the Molluscs are the Jointed-Footed Animals or Arthropods, represented on the shore by Crustaceans, such as crab and hermit-crab, sea-slater and sand-hopper, acorn-shells and water-fleas. Clambering about on the seaweeds and zoophytes there are quaint "Sea-

spiders" or Pycnogons, perhaps related to both true spiders and Crustaceans. A few true spiders among the rocks, some insects near high-tide mark, and an occasional centipede must also be included in the shore-fauna.

WORMS.—The higher worms or Ringed Worms (Annelids) are well represented on the shore; but one must dig to see the best of them. Thus the yard-long many-footed *Nereis virens* burrows in the sand close to the rocks; the castings of the fisherman's lobworm (*Arenicola*) are much in evidence on the flat beach; the strange sea-mouse (*Aphrodite*), shaggy with iridescent bristles, is often cast up from greater depths. The sand-binding worm (*Lanice conchilega*) makes tubes of sand-particles neatly fastened together; the lime-tubes of *Serpula* are common on shells, and of *Spirorbis* on seaweed.

Besides the higher worms or Annelids, with a ringed body, there are many others of lower degree. Where there is rotting we may find thousands of small threadworms or Nematodes, and in the shore-pools there are Planarians or "living films" which glide along mysteriously by means of invisible lashes or cilia.

Of Uncertain Position.—There are many seashore animals whose relationships are obscure. Thus there are the Polyzoa, to which the common Sea-Mat (*Flustra*) belongs—the animal on which Darwin wrote his first scientific paper. The Polyzoa form a large class, with a great variety of representatives, some seaweed-like (*Flustra*), till you look into them; some coral-like (*Cellepora*); some gelatinous (*Alcyonidium*); some like zoophytes (*Gemelaria*), but ever so much higher in structure.

Echinoderms.—The prickly skinned animals are represented by star-fishes, brittle-stars, sea-urchins, and sea-cucumbers, forming a well-marked "kenspeckle" class, with a great tendency to become very calcareous, least so in the sea-cucumbers, most in such sea-urchins as the sand-dollar. It is a most interesting sight to watch the common star-fish creep up the vertical surface of a submerged rock by means of its remarkable hydraulic locomotor system, while the sea-urchin, when moving on a flat surface, hobbles along on the tips of its five teeth!

Stinging Animals.—Sea-anemones nestle like flowers in the niches of the rocks. In

deeper water there are Alcyonarians, such as Dead-Men's-Fingers, often thrown up in great quantities after searching storms. In warmer seas the branched Sea-fans or Gorgonians are very common. Everywhere there are zoophytes or hydroid colonies, some of which give off swimming-bells or medusoids in the summer season. When a Stinging Animal (or Cœlenterate) becomes very calcareous it is called a coral, and so there are corals related to sea-anemones (such as reef-building corals and cup corals), others related to Alcyonarians (such as the precious red coral and the organ-pipe coral), others related to hydroids (such as the close-grained millepores).

SPONGES.—Apart from the family of fresh-water sponges (Spongillidæ)—doubtless emigrants from the shore—all sponges are either shore-animals or deep-sea animals. In other words, they are sedentary and require a substratum on which to grow. The Crumb-of-Bread Sponge (*Halichondria panicea*) grows on the shore-rocks, with exhalant openings like the craters of volcanoes; the Purse Sponge (*Grantia compressa*) often has to endure prolonged exposure at low tide; the Bath Sponge

(*Euspongia*), found in the Mediterranean, the West Indies, and Australia, often grows at depths readily reached by a long fork.

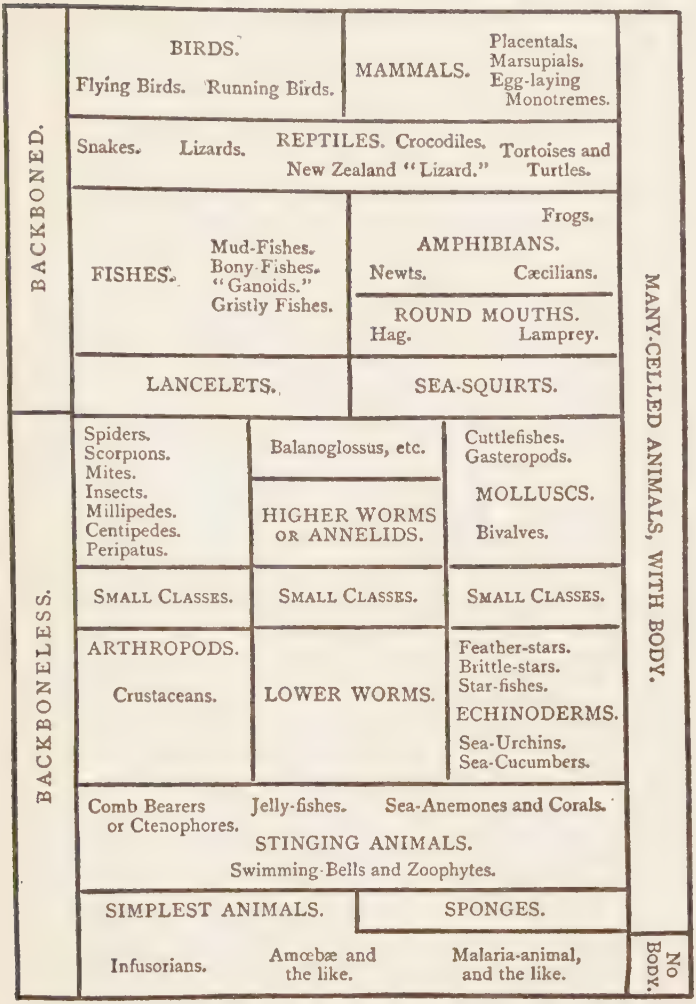
SIMPLEST ANIMALS.—Very abundant on some shores are almost microscopic chalk-forming animals or Foraminifers which glide about on seaweed by means of outflowing and retractile threads of living matter. In all the pools and shore-waters there are many kinds of Infusorians, which propel themselves rapidly by means of lashes of living matter (cilia or flagella).

Any book on shore Natural History will supply information about the animals on our list. The meaning of the list is just to show that the shore gives hospitality to a *very* representative assemblage of animals. We add a scheme of classification, which may be useful at different parts of our study, to show how certain animals stand in relation to others.

A DIFFICULT PLACE TO LIVE IN

The school of the shore is a hard school. It must be an interesting and stirring place to live in, but no one could call it easy. There

THE ANIMAL KINGDOM



are stormy days when the waves are literally breakers. There are fresh-water floods from inland, smothering masses of jetsam from the sea, and clouds of wind-driven sand from the beach and the dunes. In the polar regions there are difficulties due to the ice; in the equatorial regions there are difficulties due to the scorching sun.

Many problems are presented by the differences between tide in and tide out: animals that have been bathed in water for many hours are left high and dry. Let us look at a few of the solutions.

All animals require oxygen to keep the vital processes agoing, for there is no living without combustion. Oxygen is required to keep the fire of life burning. Now marine animals find the indispensable oxygen mixed with the water, and seashore water, where there are waves, is very rich in oxygen. But an animal accustomed to use the oxygen mixed with the water cannot suddenly change and become able to use the oxygen mixed with the air. This is one of the problems raised by the outgoing tide.

The Purse Sponge (*Grantia compressa*)

keeps a big bubble of water in the cavity of its body, and this serves to mediate between the living cells and the dry air. The bivalves, like mussels and oysters, keep the two halves of the shell firmly closed, and imprison enough of sea-water to keep the delicate gills and skin moist for many hours. While the mussels are uncovered at low tide the shells are never opened, and the animal remains quiet, not feeding, scarcely breathing, simply waiting until the sea returns. Periwinkles, buckies, and many other sea-snails have a very effective way of closing their shell by means of a hard plate attached to the hind end of the muscular "foot." When the animal withdraws into its shell, this lid (operculum) closes the mouth of the shell and fits very neatly. If we watch a periwinkle walking about on the floor of a pool we see that it glides along on its "foot," and that the head with its horns is also protruded. But if we pick it up the head and the foot are immediately withdrawn, and the animal is safe behind its closed door.

The limpet needs no door to its shell, because it clings so firmly to the rocks by its sucker-like foot that it is very difficult to dislodge. Its shell is so thick that the water within

it does not evaporate, and the limpet is safe, too, from being injured by the waves. But it is not altogether safe from other animals, for some birds, especially the oyster-catcher or sea-pie, have discovered exactly the kind of sudden sharp stroke of the bill that is needed to knock a limpet off its rock, and once it has let go its hold it is a helpless victim. When the tide covers the limpet's rock it relaxes its hold and slowly moves off on its foot to the nearest seaweed patch where it cuts, with the long, toothed, rasping ribbon or file in its mouth, the grassy blades on which it feeds. Before the tide has ebbed it makes its way back to its rock, if it has not wandered too far and lost its way, and fixes itself in the exact spot in which it was before. In some cases it keeps to this spot so persistently that a little pit corresponding in size and shape to its shell may often be seen in the rock. Where all the rock is smooth the limpet does not trouble to return to its starting-point, for every spot is very much the same.

Some molluscs, whose shells are not large enough to enclose them comfortably, or to protect them effectively, have learnt to bury themselves in the sand, and so to secure mois-

ture and safety. The animal which lives in the familiar razor-shell of our shores burrows straight downwards with its foot into the sand, where it lies so well concealed that it is not easy to discover it alive. For even if we see above the sand the little jet of water it shoots up from time to time through its breathing tube, the animal burrows away so rapidly that it is not easy to reach it.

Still more remarkable is the fact that some bivalves, such as the one known to fishermen as the piddock, burrow, or rather bore, into the rocks themselves. We can see their holes very easily, especially when the rock is one of the softer kinds such as sandstone, and we may sometimes see the breathing tubes of the piddock at the mouth of its long burrow; but these are very quickly withdrawn as we approach. The hole is too narrow and long for a crab's claw or a bird's bill, and the animal can only be got at by breaking open the rock.

This mollusc uses its "foot" for burrowing into the rock just as its sand-burrowing relatives do; but there is a difference in the foot. Though it looks quite soft, it has, embedded in its muscular substance, a layer of sharp, hard crystals, and these slowly wear away the

rock as the animal patiently scrapes. The crystals in their turn are worn away by the rock; but they are continually being renewed. Thus by means of this adaptation the boring Pholas secures three things: first, the necessary moisture and shelter from sun or frost to keep it alive while the tide is out; second, security from being dashed to pieces by the waves; and third, relative safety from the attacks of hungry enemies.

Molluscs are not the only animals that have learnt these ways of protecting themselves. Many worms burrow in the sand, and a few bore into the rocks. Flexible worms cannot have shells in the strict sense, for shells are made by the living skin; but they often build round their bodies sheltering tubes of lime or of grains of sand, or bits of shell or other substances cemented together, and they withdraw their delicate tentacles into these when danger threatens. Fragments of the different kinds of tubes made by different kinds of worms may often be picked up on the shore.

Crabs and some of their relatives have also the habit of burrowing in the sand, shovelling it aside with their great claws or with their legs. The big crabs, indeed, do not need this

habit much for protection, for their thick, hard shell covers the gills and prevents evaporation; they are sufficiently active to be able to get to a pool or a sheltered crevice under a rock whenever occasion arises; and their strong claws and pugnacious spirit are enough to keep off most enemies except still bigger crabs. Some of the other members of the family, however, such as the burrowing prawns, tunnel in the sand near low-tide mark, and live an almost underground life.

THE STRUGGLE OF THE SHORE

A haunt with a crowded population of all sorts and sizes, a haunt where the most constant thing is change, a haunt bristling with difficulties and hemmed in by limitations; there is bound to be much *struggle* on the shore. But we should try to make it clear to ourselves that the "struggle for existence" is a technical phrase which includes much more than a life-and-death competition around the platter, much more than what we get a symbol of when the pigs elbow and jostle one another at the feeding-trough; it includes all the answers-back that living creatures make

to the difficulties that beset them and the limitations that hem them in.

The struggle on the shore is partly for food—some of which is always being carried out to sea; partly for foothold—for a good niche is a treasure; partly for the oxygen mixed with the water—the oxygen which is always necessary to keep life going; partly against risks of dislodgment, smothering, and drought; partly to get elbow-room in self-expression; and partly to secure the safety and welfare of the young ones. The "struggle" is sometimes an endeavour after well-being. It may be with fellows of the same kind—one hermit-crab against another; it may be with foes of quite different race—mussel against star-fish, limpet against oyster-catcher; it may be between animals and Fate—the physical forces of wind and wave, of sand and sun. The struggle is manifold.

In our study of the *Wonder of Life* (1914) we have referred to the struggle for *foothold* on the shore. "It is important, for instance, that the limpet, which makes little journeys in search of seaweed to nibble, should not go too far, else it will not find its way back, and will have lost the spot which its shell has

grown to fit. It is curious, too, to see the American Slipper-Limpet (*Crepidula*)—one growing on the top of another to the number of four or five—suggestive of the root-idea of a sky-scraper." It is very interesting to take a stone from a deep pool, or from the floor of the sea in shallow water further out, to see how many different kinds of creatures take advantage of this pedestal. One stone from Clare Island bore fourteen different kinds of "moss-animals" or Polyzoa.

Truly, the shore is a place of struggle. Is there any other haunt where we see so clearly the truth of Tennyson's words—

> "That life is not as idle ore,
> But iron dug from central gloom,
> And heated hot with burning fears,
> And dipt in baths of hissing tears,
> And batter'd with the shocks of doom
> To shape and use."
>
> *In Memoriam.*

Some one said long ago that a great part of life is connected with the conjugation of the verb: To eat; and we realise how true this is when we study the life of the shore. "I eat, thou eatest, he eats . . . they eat." "I shall eat . . . they shall eat." "I have eaten . . . they have eaten." "They have been eaten."

It is fairly safe to say that no seashore animal ever says, what a man might say with a shark after him: "I shall be eaten." It is certain that none ever says: "I have been eaten." There is grim truth in this saying about the conjugation of the verb: To eat; but the truth is one-sided unless we remember that the animals are also conjugating the verb: To love, and often, also, the verb to conquer. "Love" and "Hunger," both in inverted commas, are the pivots on which all life swings.

THE CIRCULATION OF MATTER

Animate nature is run on what may be called a scheme of successive incarnations. Matter is always passing from one *embodiment* to another, and nothing is ever lost. The minute plants free in the water and the fixed seaweeds, great and small, all feed on the sea itself and the air which it holds in solution. They are bathed in a nutritive solution of salts and gases, which their living matter, with the help of the sunlight, lifts on to the plane of life. In technical language, they build up carbon-compounds by photo-synthesis.

But animals get their food from the plants,

or from remains of the plants, or from other animals which have fed on plants. So one incarnation or embodiment follows another in long chains, and this is the circulation of matter.

It has been calculated that—

> One pound of cod means that the cod, to make it, had to eat ten pounds of whelk or buckie;
> One pound of buckie means that the buckie, to make it, had to eat ten pounds of sea-worms;
> One pound of worms means that the worms, to make it, had to eat ten pounds of vegetable sea-dust.
> We mean by the vegetable sea-dust the microscopic plants and their remains.

Sometimes the chain is longer, sometimes shorter, but we cannot understand the economy of the sea at all until we get a firm grip of the idea, which the chemist Liebig first made vivid, of the circulation of matter. It is a modern version of what one of the Greek philosophers, Heraclitus, said: ALL THINGS FLOW.

CANNIBALISM IN THE CRADLE

The struggle for existence means all the answers-back that living creatures make to surrounding difficulties and limitations. It includes experiments in co-operation and mutual aid, as well as experiments in competition. At one time it may take the form of increased parental care; at another time it may mean a sharpening of teeth and claws.

We must not blink those cases where the struggle is terribly keen—for immediate life or death. Let us take an instance. Fastened to the rocks there are great bunches of chaffy capsules—the egg-cases of the Great Whelk or Roaring Buckie (*Buccinum undatum*), whose shell children hold to their ears. Sometimes the bunch, made by several whelks working together, is as big as one's head. In each capsule there are many developing eggs, and as these hatch out into larvæ they turn upon one another. Those furthest advanced eat the others—the leaders the laggards—till only a few are left in each capsule. This is struggle to the death at the very threshold of life. It is cannibalism in the cradle. The

empty bunches are often torn off by the waves and thrown up on the beach. If a capsule is carefully examined, an opening will be seen on the inturned flatter side—the opening by which the surviving larvæ emerged. The same grim story is true of the neat vase-shaped capsules, first pinkish and then straw-coloured, which the small Dog Whelk (*Purpura lapillus*) fastens to the rocks, very often to the under side of a shelf. Many are called into life, but few are chosen to survive.

SHORE SEAWEEDS

It is a great sight when the seaweeds are uncovered on a rich foreshore at the lowest tide of the year. If we put on old clothes and boots and wade out among them, very, very cautiously, because of the slipperiness and the danger of concealed deep holes, we get our reward, especially if we take scientific imagination as our staff. We find ourselves in the midst of a rich and varied vegetation, part of which is older than the hills. We are in the midst of the plants of the early ages of the earth's history.

A distinguished Oxford botanist, Dr. A. H.

Church, has pictured three great chapters in the history of plant-life.

(I.) After the earth had greatly cooled down, the condensation of the water vapour formed a great sea covering the whole surface of the earth. In this sea there lived minute single-celled or bodiless green plants, each sufficient unto itself. Some of these Plankton plants were the ancestors of those which now abound near the surface of the Open Sea.

(II.) By and by the buckling of the sea-covered earth's crust brought part of it within reach of the light, and supplied an illumined sea-floor on which plants could fix themselves and grow big. This was the beginning of the shore vegetation, the beginning of a substratum, the beginning of what we ordinarily call sea-weeds. And as they were fixed creatures, it was necessary for them to show, not only means of self-preservation, but means of dispersal, ways of continuing their kind. Some of the free-swimming plants that settled down grew long threads, others spread out into fronds, others forked and branched like the most beautiful lace. Ages passed, and there was a great race of seaweeds. Some of those now living are a hundred feet long.

(III.) According to Dr. Church's interpretation, the gradual raising of the sea-floor in certain places led to the first dry land, and some of the seaweeds, which had become very complex plants, were transformed into land plants. If this is true, it was a great change. The roots of seaweeds are only anchors or hold-fasts; they would require to be equipped with rootlets and root-hairs for absorbing the water and salts from the young soil. And the whole surface of the sea-plant, suited for absorbing water and salts all over, would have to become the gas-absorbing surface of the land-plant. Moreover, there would need to be a system of vessels inside the pioneering land-plant for transporting the raw materials and the manufactured materials from one part of the plant to another; and this is only beginning in seaweeds.

Of course, when we speak of transformation, we must not think of the old stories of the yellow frog who was suddenly turned into a fairy prince, or of the followers of Diomede turned into birds, which a scholar-naturalist has identified as Shearwaters. Nature's is no quick magic, but here a little change and there a little change, so gradually, so slowly,

that if living man had seen the transformation he would have said that the living creature was not changing at all.

Whatever the history of seaweeds may have been, they are splendid and beautiful plants to-day—not half enough appreciated. But without saying more about this we may notice an important fact in regard to their colours. The green seaweeds are nearest high-tide mark; lower down the brownish ones are in the majority; most of the red ones are in still deeper water. All the three sets have got the precious green pigment or chlorophyll, which enables the plant to utilise the energy of the sunlight; but in the brown and red seaweeds the green is disguised by other pigments. Some say that these other pigments help the plant to make the most of the decreasing light, and that red is better than brown. So the red seaweeds are most abundant in the deepest waters where the light is least.

FOOD-GETTING ON THE SHORE

What food supplies are available for animals on the seashore?

(1) There are, first of all, the living sea-

weeds on which some animals browse, such as the Pellucid Limpet (*Helcion pellucidum*), well known for its beautiful blue-marked shell. Some animals that look as if they were eating the seaweed are feeding on microscopic plants on the surface of the fronds. Along with the seaweeds we must take the sea-grass, Zostera, a flowering plant very abundant in some shore waters. (2) There is, secondly, the result of the breaking down of seaweeds and sea-grass, the vegetable débris, the plant-dust. (3) There is, thirdly, the multitude of minute free-swimming and free-floating plants, such as Diatoms and Desmids. These are exceedingly abundant in near-shore waters, and get swept out to form Open-Sea Plankton. The shore-waters serve as a nursery for the Open Sea abundance of minute plants. (4) There are the minute free-swimming animals, some of which are hardly distinguishable from plants. (5) There is the material, both animal and vegetable, brought down from inland by rivers and streams, sometimes helped by the wind. We are not including the mineral matter brought down which serves to feed the shore plants. (6) There is the jetsam brought in from the sea, for the receding tide sometimes leaves

on the beach countless numbers of creatures that have come too near the shore. We have seen a brownish line of millions of the pinhead-like Noctiluca extending far along the sand.

Sometimes there is an unexpected windfall of food! Thus one writer tells us that a hurricane lasting for days, at the time that a particular moth (called the nun) was swarming, blew such numbers of these out to sea, that, when they were washed up by the tide, their dead bodies formed a wall 6½ feet broad and 6 feet high, which stretched for many miles along the shore. The same kind of thing has been noticed many times in warmer regions, when the locusts were caught in a storm during their migration.

But there is one thing we must remember about the abundant supply of food on the seashore—it is not very regular, and it never lasts long at a time. The incoming tide may throw it up one day and the outgoing tide may carry it away the next—carry it so far that it is never brought back again. For if it gets beyond the shallow-water area it sinks to the bottom at the "mud-line." It is not wasted even then—"Nature is ever a careful housekeeper"; but it is no longer available for the

shore animals. So these have to be on the *qui vive;* they must feed while they can, and take as much as they can. No doubt they can get a good living, but they cannot get it easily. One of the most important lessons that the inhabitants of the shore have to learn is to be always on the alert, and to make the most of their chances.

Let us take some particular cases of food-getting. Encrusting the rocks in many places there is the Crumb-of-Bread Sponge (*Halichondria panicea*) with large exhalant apertures where the water is swept out, and minute pin-prick holes all over the surface by which the water is swept in. After their early youth is past, sponges are fixed animals, and one naturally thinks of them as easy-going. But they have to work hard for their living. They obtain their food from microscopic creatures and nutritive particles in the water, and in order to get enough they have to pass large quantities of water through their body every day. If an animal's body be compared to a city, and the tissues to streets, and the cells composing the tissues to houses and workshops, and the jostling particles of living matter inside the cells to the people themselves, we would compare a

sponge body to a city like Venice, which is traversed by canals, bringing in food and useful materials, and carrying away waste. For the sponge's body is traversed by inhalant canals, bringing in food and oxygen (both carried by the water), and bearing out useless particles and waste products. The water, as we have said, passes in by minute pin-prick holes all over the surface of the sponge; it passes out by the large openings often about the diameter of a lead-pencil. If a glass tube be carefully fitted into one of these exhalant apertures, and one need not be afraid of hurting the sponge, the water will be forced up into the tube above the level of the surface of the pool. Where does the force come from? The pressure is due to the ceaseless activity of lash-bearing or flagellate cells, situated in chambers at the junction of the inhalant and exhalant canals. On their lashing the whole life of the sponge depends. Does it not work hard for its living?

The sea-anemones nestling in the niches of the rocks, some of them like chrysanthemums when spread out, how do they get their food? They wait for creatures, *e.g.* small crustaceans, to touch their expanded tentacles, which are covered with explosive stinging-cells and

grappling-cells. Just as we draw back our finger from a hot plate without even willing it, because of a circuit between nerve-cells that feel, nerve-cells that command, and muscle-cells that obey, so the sea-anemone folds its tentacles about an incautious worm. This is called reflex action. The sea-anemone may be deceived by giving the tentacles a little roll of wet paper to catch; but after it has been cheated twice or thrice it has had enough and will not close up any more. Sometimes it catches too big an animal, like a periwinkle, which struggles hard and bursts through the enswathing tentacles. The sea-anemone can flourish for a long time without more than microscopic food; it might be called an easy-going feeder. One has been known to live for sixty years.

Right up to the high-tide mark on rocks, pillars of piers, stray pieces of wood, and even on living animals, like crabs, we see a crusting of rock-barnacles or acorn-shells. When the tide is out the roof of the rampart that encloses the animal is kept tightly shut; but as soon as the water, or even the salt spray, reaches it, the acorn-shell opens its four valves. When it is covered with water it begins to feed without

losing a minute, and we are rewarded if we kneel down beside a pool and watch operations.

From between the valves there are protruded

FIG. 2.—ACORN-SHELLS OR ROCK-BARNACLES (BALANUS). Of two kinds, large and small. Notice the Outer Rampart, the Movable Roof of four pieces, and the six pairs of Curled Feet wafting the Food into the Mouth.

six pairs of curl-like, bristle-bearing limbs, each with two branches; and with this sifting net the little crustacean sweeps the water,

wafting minute creatures and nutritive particles into its mouth. Professor Huxley compared the acorn-shell to a shrimp fixed head-downwards, and kicking its food into its mouth with its legs. But it is a peculiarly graceful kind of kicking! Many of them must expend much energy before they sift out a meal from the clear water. They live in castles; but not castles of indolence. The acorn-shells are relatives and probably descendants of the stalked barnacles which fix themselves to wooden ships and floating logs. Like these they are free-swimming in their early youth; but they fix themselves eventually by their feelers and settle down. A rampart of lime is formed round about, and the animal is cemented down for the rest of its life. Not a very exciting life, perhaps, but a very safe one, for no waves are strong enough to wash the barnacle from its rock. Sea-urchins have meals of barnacle when they are tired of sea-weeds, and dog-whelks also browse on them; but they hold their own well. Their eggs are washed out by the tide and hatch in the open water, and there we also find the transparent feather-like moults of the adults which have been cast in the pools.

Sponges, sea-anemones, acorn-shells are fixed animals, and they depend for food on what they can sweep in from the water, or on what they can catch as it passes by. But we must take some examples of more vigorous ways of feeding on the part of animals which roam about from place to place. The periwinkles, such as *Littorina littorea,* which is one of the poor man's "oysters," creep about browsing on delicate seaweeds, and it may be noticed that those sea-snails which have an unbroken outline to the mouth of their shell are vegetarian, while those with a deeply in-cut notch at the mouth of the shell (a groove for the protrusion of a breathing tube) are carnivorous. The vegetarian Gasteropods are palatable; the carnivorous ones hardly ever. So if we are wrecked on a desert island we must begin our seashore meals with those sea-snails that have *no notch* at the mouth of their shell.

Very different from the periwinkles are the whelks and "buckies" which roam about in search of animal food. We often find on the sandy beach one of the valves of a bivalve shell, *e.g. Venus Gallina,* with a hole neatly bored through it, as neatly as if it had been made by a gimlet. In many cases this hole

has been made by a carnivorous Gasteropod called Natica, which has a boring gland on the underside of its proboscis. This gland is pressed against the bivalve shell and the sulphuric acid which it secretes dissolves a hole right through. When the perforation is made, the borer often uses its rasping ribbon to enlarge it.

THE STORY OF THE ANGLER

One of the queerest of queer fishes is the Angler or Fishing Frog (*Lophius piscatorius*)—a fish that fishes. It is rather a lazy creature, of long pedigree, and of big appetite. In shallow water off-shore it often shuffles along with its strong fore-fins and settles down on an open space among the seaweed. Curious tags of skin about the head and body are very like waving fronds of seaweed, and that is all to the good. The first three fin-rays of the dorsal fin are long separate rods, and the first, which is particularly mobile, bears a lappet of skin dangling at the free end—the bait at the end of the angler's line. Circumstantial evidence points to the conclusion that the angler really fishes with its fishing-rod. In

some of its deep-sea relatives the bait or lure is luminescent. Fishes are often attracted to dangling objects, which doubtless pull the trigger "Food." But whatever be the precise use of the fishing-rod there is no doubt that the angler catches many fishes.

The creature's head is extraordinarily broad, and its gape is a terror. The angler seems "All Mouth." A fatal gape it is, for the sharp teeth along the jaws point backwards and are hinged at their base, yielding at once if we press them inwards, but rising in opposition if we draw our finger the other way. What a simple trap, and yet so subtle! A broadening out of the jaws is not very remarkable; but add to that a fishing-rod and a loose-hinged attachment of the backward-pointing sharp teeth. If the incautious victim has begun to explore what must seem to it just an interesting opening below the dangling lure, *there is no return.* In some cases the Fishing Frog manages to submerge much of its clumsy body in the sand. The dorsal fin-rays stand out in all innocence; the bait dangles above the mouth; the victim indulges its scientific spirit of investigation—and then the trap snaps.

The eggs of the angler are found floating in

the open sea, embedded in little compartments in a big drifting sheet of violet-grey slime, many feet long. After a while the eggs become separated from the sheet and float singly. The newly hatched young one floats also, with its heavy head downwards (see Fig. 7, p. 93), and the tip of its tail just touching the surface film. It is still living on the yolk of the egg which is uppermost in the water. After a fortnight has passed the yolk is exhausted; the young fish is superficially like a tadpole; it opens its mouth and begins to fend for itself. For a long time, however, it lives an Open-Sea life, and it has an extraordinary appearance, due to the elongation of its fin-rays into flexible streamers. These have the same use as the slime round the eggs, they secure flotation, first at the surface, and then in the upper layers. This is, on the whole, a very safe cradle, and there is an abundance of living minutiæ to eat. Gradually the head of the larval angler broadens out enormously behind the eyes, and these are shifted to the top. The seaweed-like tags of skin become numerous, the long fin-tassels disappear. The young fish comes near shore and sinks to the bottom—there to remain for the rest of its life.

THE STAR-FISH AND SEA-URCHIN FIGHT

The star-fish is a soft-mouthed animal, without anything in the way of teeth or jaws, but it is a thoroughgoing carnivore. It does much harm on the oyster-beds, engulfing the small oysters in its capacious protrusible stomach. It is fond of mussels, and it can actually open the valves by hunching itself up above the mussel and persistently pulling in opposite directions with the suctorial tube-feet of two of its arms. But who would think of a star-fish tackling a small sea-urchin, covered all over with spines like a hedgehog, and equipped with hundreds of little snapping blades (called pedicellariæ), like scissors with three blades. When these snapping spines are touched, they clinch; and some of them are poisonous.

Nothing daunted, if we dare use such a phrase in regard to an animal that has not a vestige of brains, not even one nerve-centre, the star-fish lays one of its arms on the prickly sea-urchin. The hundreds of tube-feet on the under surface of the arm are promptly nipped by the sea-urchin's snapping spines. The star-fish withdraws its arm, and the snapping spines, unable to let go, are wrenched off.

Then another arm is used, and another, and another, until the star-fish has *disarmed* the small sea-urchin. Then out comes the elastic digestive stomach. This shows remarkable persistence on the part of a brainless animal.

SHIFTS FOR A LIVING ON THE SHORE

Of all the haunts of life the shore is most varied in its life-saving devices. We like to call them "shifts for a living," because they are on so many different levels of behaviour. In some cases the animal probably knows what it is doing, in some dim way at least, as when a crab deliberately rubs pieces of sea-weed on the back of its shell so that they catch on the bristles and grow there. In other cases the animal probably does not know what it is doing, as when the star-fish surrenders an arm that is seized.

What an armoury of weapons there is on the shore—stinging-cells of sea-anemones, the lasso of a ribbon-worm, the forceps of a crab, the rasping file of a whelk, the parrot's-beak-like jaws of a cuttlefish, and so on up to the tusks of a walrus. What a variety of armour too,—the prickly test of a sea-urchin, the or-

nate carapace of a rock-lobster, the unbreakable shells of molluscs, the scales of fishes often sharp and formidable, and so on up to the complicated encasement of the edible turtle.

MASKING

The "walking wood of Birnam" was an episode in Scottish history, immortalised in Shakespeare's *Macbeth*, where a band of soldiers camouflaged themselves by cutting down branches of trees and carrying these with them as they stealthily advanced. So some crabs on the seashore fix seaweeds on the back of the shell and mask themselves effectively. They can steal upon their victims; they can efface themselves in the eyes of their enemies. Sometimes the cloak consists of zoophytes, or pieces of sponge, or half of the tunic of a sea-squirt; but oftenest it is a cloak of seaweed. It is as if the crab carried a garden on its back. The camouflaging is often shown by the sand-crab (*Hyas araneus*) and by the narrow-beaked crab (*Stenorhynchus longirostris*) ; but it is seen in many others. The disguising seems very deliberate on the crab's part, and if the disguise is picked off, the crab often sets about clothing

itself again. One of the hermit crabs (*Pagurus cuanensis*) in deeper water has its borrowed shell frequently surrounded by a bright orange sponge (*Suberites domuncula*), with a strong odour, a disagreeable taste, and countless flinty needles—which fishes naturally leave alone!

A LIMB FOR A LIFE

Many different kinds of animals, especially those with rather lanky limbs, practise a curious kind of surrender—a limb for a life. And what they surrender as a ransom for their life they can regrow at leisure.

This is well illustrated by many star-fishes. If an arm is pinned down by a stone, or seized by an enemy, or if a sea-slug has settled on an arm and cannot be dislodged, the star-fish manages to break off the arm at the base. In so doing it is behaving as we behave when we draw back our finger from a very hot plate, or shut our eye when a stone is about to strike it, or cough when a crumb of bread threatens to "go down the wrong way." We do not think about doing any of these things nor exercise our will; what we do is called a reflex action, carried out by means of pre-arranged linkages

of nerve-cells and muscle-cells. So is it in the star-fish when it surrenders an arm. We know that the star-fish does not do this deliberately, for it has a very poorly developed nervous system. There is a strand of nerve-cells up the middle line of the under surface of each arm, and these are united in a pentagon around the mouth; there are also many scattered nerve-cells; but there is no brain, not even a single nerve-centre or ganglion. The star-fish does not know what it does, but it has *somehow* in its constitution learned in the course of time that it is better that one member should perish than that the whole life should be lost. Brittle-stars give off their arms very readily; sea-cucumbers are less polite, for they discharge their insides in the spasms of capture; sea-urchins have nothing that they can give away save their spines. We see the same sort of surrender when the lizard gives off its tail, and we find many cases among insects and spiders. It is very marked in the harvest-men, who stalk about in the evening among the stubble, with legs over twenty times the length of their body. The self-mutilation ("autotomy") is also very common among Crustaceans.

A common accident on the seashore is that a crab gets its leg badly broken by a moving stone. When that happens the crab goes in for surgery. By a very forcible contraction of the muscles at the base of the damaged leg the crab manages to break it off across a weak line. And just below this breaking line there is inside the base of the leg a two-flapped membrane which closes up the wound and prevents bleeding. Inside the bandage a new leg is formed in miniature, and at the next moult this shoots out like a Jack-in-the-box, and soon hardens.

COLOUR CAMOUFLAGE

The common shore-crab (*Carcinus mænas*) occurs in many colours when it is young, and these sometimes harmonise exactly with the rock of the pool in which the particular crab lives. But there is no change of colour except after a moult. It is different with the Aesop Prawn (*Hippolyte varians*) which takes on the colour of its surroundings, both when young and when adult, and can change from one colour to another with ease. It has a large repertory—red, yellow, blue, orange, olive,

violet, brown, and green, and it is often almost perfectly self-camouflaged among brightly coloured seaweeds.

Not less subtle is the rapid change of colouring and pattern in flat fishes like plaice and dab. Very quickly they put on the hue and the marking of the sand or shingle on which they are resting. When on sand they usually cover themselves quickly, all except the eyes which protrude and look about. Blind flat fishes do not change colour, so we know that the message from the outside world first affects the eye. It travels to the brain, and by the nervous system to the colour-cells in the skin which can change their size and position. In some instances the change occurs in a minute or two, and it gives the fish a garment of invisibility.

In the aquarium at New York there is often a startling display of coral-reef fishes from the Bermudas and similar places. Their colours are brilliant, and their patterns are almost incredible. It seems to some naturalists quite impossible that these colours and patterns can have concealing value, partly because they are so conspicuous, one might almost say daring, and partly because they

differ so much in fishes from the same reef.

So it has been suggested that they are *warning* colours, useful in impressing enemies with the fact that many of these brilliant fishes are unpalatable and best left alone. And another view is that coral-reef fishes are so safe, with so many holes and corners to play hide-and-seek in that they can afford to be any colour. On this view, the colours are of no more use than the colours of withering leaves.

On the other hand, Mr. W. H. Longley, who has walked about on the floor of the coral sea and watched the fishes for hours, maintains that many of the most brilliantly coloured are very well camouflaged when they are in the particular kind of corner that they like best as a home. Some have two kinds of coloured pattern, suited for two haunts—a sort of Jekyll and Hyde business. Some are longitudinally striped or with no pattern when on the move and cross-striped when they settle down. It looks as if there was a great deal of useful camouflaging.

LOVE ON THE SHORE

The business of living creatures is two-fold—caring for self and caring for others. Perhaps we have said enough about caring for self on the shore; what about caring for others? The mother-seals nurse their young ones among the rocks, and many birds, such as guillemots and razor-bills, puffins and kittiwakes, make their nests on the cliffs. When we see the narrow ledges on which the guillemots and the razor-bills lay their eggs—just one for each bird—we wonder that there is any successful hatching at all. The wind searches every shelf, and there is such a crowded coming and going of mothers that the egg has every chance of being jostled. But Darwin asked naturalists to notice the pear-like shape of the egg and the particular way in which it moves when it is twirled in an eddy or jostled by the bird's feet. Because of its shape it tends not to *roll,* but simply to rotate on its short axis without moving from its place. If we give it a vigorous twirl on a smooth table, it simply rotates without rolling. For this reason, then, it does not fall off the narrow ledge into the sea. This is a simple example of what is

meant by a fitness or *adaptation*—some peculiarity of structure or habit which is particularly well suited for special conditions of life; and one of the pleasures of Natural History lies in the discovery of these fitnesses.

The turtles come ashore from the warm seas and lay their eggs in the sand, and the mothers linger till their young ones are hatched. The Edible Turtle is a vegetarian, living on seaweeds, and must therefore keep within the shore-area in the wide sense. It has not far to migrate when the time of egg-laying draws near. But the fish-eating turtles of the Open Sea, like the Hawksbill Turtle and the Snapping Turtle, often make long journeys before they find suitable places for egg-laying on the shores of island or continent.

The venomous sea-snakes, well known in the Indian Ocean, are tenants of the Open Sea, but some of them at least come to the shores at the breeding season. They do not lay eggs as the turtles do, but bring forth their young as fully formed little snakes, and it is interesting to know that the mother often remains for a while with her children, until they are able to fend for themselves and follow her out to sea. This is what we mean by "love" on the

seashore, and however big we make the inverted commas we cannot persuade ourselves that the maternal care of the sea-snakes is not on the same line as that of any human mother, vastly finer as that usually is.

The quaint fish called the Lumpsucker or Cock-Paidle (*Cyclopterus lumpus*) lays a big bunch of reddish eggs in a corner of a deep rock-pool low down on the shore, and over this the father mounts guard, driving away intruders. Every now and then he lashes with his tail very vigorously beside the mass of eggs, and this no doubt helps to aerate the eggs and to scatter away the minute particles of mud which might settle upon them. The Lumpsucker has had its hind fins (pelvic fins) shunted forwards and turned into a strong muscular sucker, and he can grip a rock when he is paddling vigorously with his tail. We suppose the Scots name Cock-Paidle refers to this paddling of the cock-fish. His paternal duties occupy him for several weeks, and observers say that while he is on guard he neglects his own meals.

There are sticklebacks on the shore as well as in fresh water, and the males make nests and mount guard over them, but this story will

keep till we come to the fresh-water haunt. Less familiar is the case of a tropical shore-fish (the Gaff Topsail), which has only a few eggs, and lives in places where the struggle for existence is very keen. What is it to do? The male fish takes the eggs in his mouth and keeps them there until they are hatched. One would think it must be difficult not to swallow them, but he fasts all the time.

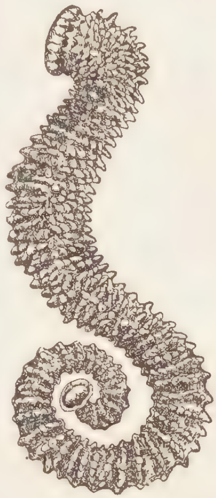


Fig. 3.—The Skate-sucker (Pontobdella).
A Marine Leech that takes great care of its Eggs.

There are many other examples of "love" on the seashore. The marine leech or Skate-sucker (*Pontobdella muricata*), a warty green animal, is both male and female at once, like earthworms and snails. It is a very careful parent, depositing the eggs in cocoons inside empty shells of bivalves, and mounting guard over them for many weeks. It is interesting to find examples of marked parental care on the lower rungs of the ladder of life. One of the humblest illustrations is to be found in a British star-fish,

Asterias mülleri, in which the fully formed young ones, skipping the usual free-swimming stage in the open water, are carried about on the mother's body.

A pretty sight is sometimes seen if we watch one of the common sand-hoppers (*Gammarus locusta*), an Amphipod crustacean, flattened from side to side, which is always busy cleaning up on the shore. If we have caught the right kind and put it in a saucer we may see quite a crowd of young ones emerging from the shelter of the mother's body, just like chickens from under a hen. They swim about like miniatures of herself, and as she slowly moves they follow, never venturing to go farther than an inch away. If we make a little splash in the water in the saucer, they hurry back below their mother, just like chickens again. Looking at this in a broad way, through a mental telescope, we see that living creatures always answer back to surrounding difficulties and limitations, and that one of the most effective ways of answering back is for the parents to look well after the children. But who wants "morals" at the end of stories!

THE STORY OF PALOLO

Every autumn, on the shore at Samoa, near where Robert Louis Stevenson used to live, there is what is called a swarm of Palolo. Now Palolo is a green worm, whose proper name is *Eunice viridis,* and its home is in the crevices of the coral-reefs. In the fall of the year the body of the worm becomes full of germ-cells,—egg-cells in the female which develop into young worms, and sperm-cells in the male which fertilise the eggs. This is of course the usual story with animals. Now in October or November, at the third quarter of the moon, for a short time after midnight, the Palolo worms become very restless. They back out of the holes among the corals and writhe in the water. The whole of the body breaks off a little way behind the head, and the headless bodies are so numerous in the water that it looks like vermicelli soup. The headless bodies burst, liberating the germ-cells; some of the egg-cells are fertilised by some of the sperm-cells, and a new generation begins. The heads creep into the crevices of the coral-reef and begin life afresh, growing a new body. Thousands of the headless, wrig-

gling bodies are washed on to the sand by the tides, and the natives gather them in baskets to make a Palolo feast. About the same time, just as if they knew, the land-crabs come down to the shore, and there is a Palolo feast for them also. The regularity of the swarm is very interesting—an inside change in the animal keeping time with an outside change in the seasons—and it should be noticed that there are in other parts of the world other kinds of Palolo worms which "swarm" at a different time of year. The association with the moon is curious and so is the concentration to a short time after midnight. The wriggling of the headless bodies in the water is another very interesting point. But we get furthest into the heart of the queer story when we notice that whereas many worms (and other animals, like butterflies, lampreys, and eels) die in giving rise to new lives, the Palolo-worms evade this penalty. They surrender the greater part of their body, but the heads creep back into the coral reefs and begin again.

A GREAT SCHOOL

For a long time after the earth became a home of life there were no animals on land at all. As far as we can judge it was in the sea that the first living creatures lived—either in the open sea or on the shore. Whether the shore was the first haunt of life or the second it is difficult to say, but it is likely that most of the great races of animals sojourned for a long time on the shore and, as it were, served their apprenticeship there. Now on the shore there are, as we have seen, many spurs to adventure and many outside changes that provoke changes in the structure and constitution of the animals. The shore is a haunt where animals are prompted to play all their cards, to make experiments with all their possibilities, just as we ourselves do when we are in a tight place. The shore animals test all things and hold fast that which is good. Or, to look at it from another side, the shore has always been a place of sifting, where those creatures that were not fit to cope with the changeful, difficult, crowded conditions have been rejected. It is in this sense that we may speak of animals learning lessons on the seashore: not

learning lessons as we do, by getting ideas into our head, but rather as the races of domestic dogs or horses have in the course of thousands of years learned lessons. Inborn qualities that were unsuitable have brought penalties to their possessors, and these have been wiped out from the list of shore animals. Inborn qualities that were peculiarly well fitted for shore-conditions have brought their possessors great success, and these possessors have survived.

When useful qualities are established in a race of animals, like docility in dogs, they are not readily lost. They may be lost along certain lines of descent, just as pigment has been lost in white rats which are descendants of the common brown rat, but they are not likely to be lost altogether. So it is not fanciful to suppose that qualities, which were established among shore animals millions of years ago, may have enriched the inheritance of animals which are now far away from the shore, may even have enriched Man's inheritance. Those in the highest form of a school may not remember that they learned *anything* when they were in the junior school, though they probably learned much!

But what were the good qualities which the

ancestors of the great races of animals may have had engrained in them when they lived very long ago on the shore? They included the quality of holding tight, which leads on to endurance, the quality of biding their time—even till the tide comes in—which leads on to patience, the quality of push, which leads on to endeavour, and the quality of seizing a good opportunity, which leads on to alertness and power of initiative. These are some of the great lessons of the old school of the shore.

CHAPTER II

THE OPEN SEA

Contrast between Shore and Open Sea—The Floating Sea-Meadows—The Animals of the Open Sea—Sea-Deserts—Swimmers and Drifters—The Whale as a Great Bundle of Fitnesses—The Story of the Storm Petrel—Open-Sea Insects — Turtles — Sea-Snakes and Sea-Serpents — Fitnesses of Open-Sea Drifters—The Story of the Floating Barnacle—Hunger and Love in the Open Sea—The Open Sea as a Nursery.

BY the open sea, naturalists mean the well-lighted surface-waters well away from the shallow shelf around the islands and continents. It is not the mere surface of the water, it includes all the zones of water through which the light penetrates freely; and that, we must remember, is much farther than at the coast where the waves stir up the sea-floor and bring so many fine particles into suspension in the water, that much of the light is stopped. In the upper levels of the open sea or *pelagic* haunt, there are multitudinous minute plants mingled with the animal ten-

Plate III.—Four Open-Sea Animals.

The Portuguese Man of War, on the surface, with its cockscomb-like red float; the mother Argonaut or Paper Nautilus with its cradle-shell, made by and embraced by two of the arms; two Jelly-fishes below the surface; and a carnivorous Turtle pursuing a fish.

ants; deeper down where the light is less abundant there are more animals than plants; deeper still there are animals only.

If the shore area is the Great School of life, where animals have learned and are still learning many lessons, the open sea may be looked on as the cradle of life. There are many authorities who believe that it was there that life had its beginnings, far back in the dim past. "There can be little doubt," writes one, "that the pelagic fauna antedated all the faunas of the globe, and that from it, through a long process of modification and adaptation, have been derived the faunas of the shore, the abyssal depths, the land surface, and the fresh waters."

But this question of beginnings is too difficult for us; we must content ourselves with taking the "pelagic fauna," which means simply the animals of the surface of the sea, as we find it now. But even now we are justified in speaking of the open sea as the cradle of life, for many of the animals which, in their adult state, live amid the turmoil and struggle of the shore, spend their delicate youth in the easier conditions of the open sea. The eggs and larvæ of some fishes, too, whose home is

on or near the floor of the sea, are found floating at or near the surface.

CONTRAST BETWEEN SHORE AND OPEN SEA

The shore waters pass gradually into the open sea, and the surface zones pass gradually into the dark, deep-water zones, but the haunt which we call the open sea has well-marked characters of its own. It is a place of spaciousness, freedom, and plenty. Let us contrast it with the shore haunt. There are three great differences. (1) The seashore is crowded, the open sea is spacious; there is room and to spare for all. (2) The shore is very changeful, the open sea is much more uniform. The differences between morning and noon, day and night, summer and winter, are less marked in the open sea than on the shore. The open sea is not indeed a place of *rest,* for the pelagic animals swim or drift unceasingly, and "know no rest from birth till death." But even this movement often makes things easier, for many of them can sink or rise in the water, getting out of the glare or the heat, or coming up to where oxygen is most

PLATE IV.—GLAUCOUS GULL AT LERWICK.
Photograph by RATTER.

abundant. (3) On the shore there is abundant food, but there is a keen competition for it, and there is a tendency for many of the nourishing particles in the water to slip past and to sink down the inclined plane to the deep waters. But in the open sea there is in most places great abundance of food, and it is accessible to all. So there are three great reasons why pelagic life is easier than littoral life.

It may be objected that the open sea is the place of storms, and it is true that there are terrible days when sea and sky seem to meet in a welter of tumultuous water. But storms are more dangerous near shore than in the open sea when there is nothing to knock against, and few of them have a deep grip. Many of the very delicate open-sea animals, like the iridescent and luminescent comb-bearers (Ctenophores) sink into quiet water whenever there is a hint of white-horses. So, in spite of storms, we may say that in the open sea the barque of life sails on an even keel. One of the disastrous effects of storms is seen where one would not at first look for it, namely, among some of the open-sea birds, like gannets. The fishes and other creatures on which they feed have taken to deeper levels in the

water, which only the deep-divers can reach, and if the storm lasts for several days the gannets and similar sea-fowl begin to starve. They become weak, and they get battered. Perhaps this is part of the explanation of the fact that the gannet often stores fish beside its resting-place on the rocky island.

THE FLOATING SEA-MEADOWS

If we are to understand the life of the open sea at all, we must picture what Sir John Murray called the "floating sea-meadows,"—vast tracts of water thickly peopled by minute plants, *e.g.* those Algæ called Diatoms. On these everything else depends. For the pelagic Algæ are possessed of the chlorophyll pigment that marks all green plants, and they are thus able to utilise the energy of the sunlight to build up the simple materials of air, water, and salts into complicated substances like starch, on which minute animals can feed. Of almost all animals it must be said that they can feed only on what is living, or has been living, or has been made by something living; but green plants feed on what is not living—air, water, and salts. Therefore, in tracing

the circulation of matter, we must always begin with the plants.

In most parts of the sea, wherever the sunlight penetrates and the temperature is not too low, there are countless myriads of simple plants, "scattered like dust amid the immeasurable water masses." These minute marine Algæ are not visible to the naked eye, and it is only within comparatively recent times that their abundance, and their great importance in the chain of life in the ocean, have been fully recognised. Between Australia and New Zealand, we are told, the officers of the *Challenger,* the ship of the great ocean expedition sent out by the British Government in 1873–1876, found the water "continuously discoloured during a period of several days' sailing, and giving off the odour of a reedy pond." Elsewhere too, even in the Arctic Regions, the water is sometimes "as thick as soup."

Along with the minute Algæ there are many minute animals (Infusorians) which have got possession of the green pigment chlorophyll, and there are others (Radiolarians) which have Algæ living in partnership with them. All these form part of the fundamental food-supply of the open sea. They are eaten by

minute animals, such as the small crustaceans called water-fleas, and these may be eaten by fishes. The bodies of dead animals are broken down by microbes, and what is not devoured by other animals passes in solution into the sea-water and may be absorbed again as part of the food of Algæ. The same is true of the waste-products voided from the food-canal and kidneys of animals. Nothing is ever lost; all things flow.

The naturalists at the Plymouth Biological Station have shown that the abundance of mackerel in the spring months depends on the abundance of the minute "water-fleas" or copepods in the upper waters, and this again depends upon the abundance of minute Algæ called Diatoms and of minute animals called Peridinid Infusorians, which form a great part of the "stock" of the sea-soup. As the multiplication of the Diatoms and Infusorians in the surface waters depends mainly on the amount of sunlight in the early part of the year, we can see a connection between the sunniness of the spring and the supply of mackerel at Billingsgate. The whole world is run on a plan of successive re-incarnations. Diatom or Infusorian, first link; copepod or water-

flea, second link; mackerel, third link; man, fourth link; and so the world goes round.

This nutritive chain is interesting in theory, but it is also very important practically, for on the abundance of the floating sea-meadows, and the population of small animals which these support, there depends, in large measure, the success of the fishing industry in northern seas.

In addition to the microscopic plants there are in some places great masses of drifting seaweeds of a higher order. They sometimes occur in such enormous dense patches that they impede the progress of ships passing through them. These seaweeds do not grow at the surface but on the sea-floor in the shallow water region, and when they are torn off by the waves they are carried by currents far out to sea. They live for a considerable time floating at the surface with the aid of their numerous little bladders, but gradually they lose their vitality and finally sink slowly to the bottom. New clumps are continually being brought by the same currents, so that in some parts of the ocean seaweed is always present. The best known of these areas is the Sargasso Sea in the Atlantic, and the weed there har-

bours countless animals of many kinds, which play hide-and-seek among the fronds.

It is interesting to learn that the animals that live in the Sargasso Sea, instead of being predominantly blue and grey, are clothed in reds, browns, and dull greens, like the weed among which they hide, and they have these colours even when their relatives in the open sea are blue. Some of them have the body reddish-brown, but the fins, which have to be spread out in the open water, are blue. It is thought that the amount and intensity of light have a great deal to do with developing the different colours of animals at different levels of the ocean, but, whatever be the cause of them, there can be no doubt that their effect is often to secure greater safety for their possessors.

THE ANIMALS OF THE OPEN SEA

Can we call the roll for the Open Sea? There are many different kinds of Infusorians, among which there is the world-wide giant, Noctiluca or Night-Light, which makes the waves sparkle in the summer darkness. A giant indeed, for it is about the size of a pin-head. Many of the chalk-forming animals or

Plate V.—Open-Sea Animals: Two Finner Whales, a Storm Petrel, and a Crowd of Flying Fishes.

Foraminifers float in the surface-waters, and this is true of most of the very beautiful Radiolarians, which have usually shells of flint, and have established an internal partnership with microscopic Algæ. Perhaps it is this partnership that has made them so successful, for there are 5000 different kinds, and the number of individuals is past all telling.

The Stinging Animals are represented by swimming-bells, most of which are budded off from shallow-water zoophytes; by true jelly-fishes or Medusæ, rhythmically contracting and expanding their translucent discs; by strange colonies like the Portuguese-Man-of-War; and by the delicate Ctenophores. One of these called Venus's girdle, like a ribbon of flexible glass, iridescent and phosphorescent, is one of the most beautiful animals of the sea.

There are not a few open-sea worms, some of them, like the Arrow-worm, quite transparent; and there are actually a few sea-cucumbers which have departed widely from the sluggish habit of their shallow-water and deep-water relatives.

Jointed-footed Animals are represented by many kinds of Crustaceans, from gorgeous prawns to pinhead-like "water-fleas"; and

one must not forget the family of Open-Sea Insects.

Molluscs are represented by the Sea-Butterflies and other lightly built translucent Gasteropods, and by a number of active cuttlefishes, such as the Argonaut and some squids.

Just across the border-line separating the backboned from the backboneless animals is the class of sea-squirts or Tunicates, and it is interesting to find a few of these in the Open Sea which do not degenerate as their shore-relatives do, but keep up the promise of their youth. Others form free-swimming colonies like the brilliantly luminescent Fire-Flame, sometimes as long as one's arm, and with a light that one can read a few words by. Highly fitted for open-sea life are the Salps, sometimes like single barrels of glass, two or three inches long, sometimes in long chains, which swim gently like glass-serpents in the sea.

The rest of the roll is easy,—the open-sea fishes like the flying gurnard, some turtles and sea-snakes, some birds like petrels and penguins, and then the whales among Mammals. It is evident that the Open Sea has its share of variety.

SEA-DESERTS

Some parts of the Open Sea have only a sparse floating population compared with others. Most of the Mediterranean is poor when compared with the North Sea. To the west of Patagonia in the South Pacific there is what may be called a sea-desert: there are few fishes and few sea-birds; there are almost no floating sea-meadows. On the floor of the sea in that region there is an unusual profusion of sharks' teeth and the ear-bones of whales, which has given rise to the suggestion that these huge creatures get into the sea-desert and die of hunger before they find their way out. The teeth and ear-bones are so hard that they can scarcely be dissolved in the sea; they accumulate on the floor as relics of ill-fated visitors to the desert.

SWIMMERS AND DRIFTERS

The animals of the open sea are divided into (1) the active swimmers (technically making up the NEKTON); and (2) the drifters, or easy-going swimmers (technically making up the PLANKTON). Good examples of the energetic swimmers are the whales, both great and

small, the petrels, the sea-snakes, the herring and mackerel, the flying-fishes, the squids, and some of the prawn-like crustaceans. The drifters may be illustrated by the sea-butterflies (delicately built sea-slugs on which whalebone whales largely feed), hundreds of kinds of small crustaceans, numerous worms like the transparent arrow called Sagitta, complicated colonies like the Portuguese Man-of-War, and the sail-bearers (Velella), often seen in the Mediterranean in beautiful fleets stretching for miles. More familiar are the jelly-fishes, often borne into shallow water and left stranded in thousands on the beach.

These two sets of animals, the swimmers and the drifters, are so different that it is better to study them separately. They represent, so to speak, two different attitudes to life. One remembers George Meredith's lines:

> "Behold the life of ease, it drifts;
> The sharpened life commands its course.
> She winnows, winnows roughly, sifts
> To dip her chosen in her source.
>
> Contention is the vital force
> Whence pluck they brains, her prize of gifts."

To keep our ideas clear we must understand that animals may be tenants of the open sea

for part of their life and at home elsewhere at another period. Thus the guillemots and puffins, which nest in early summer in such vast numbers on some of the British bird-cliffs, are open-sea birds for a considerable part of the year. Many shore animals, such as crab and rock-lobster, star-fish and sea-urchin, have free-swimming larvæ in the open water, often many miles from the coast. Jelly-fishes are characteristically open-sea animals, their stranding on flat beaches being quite accidental, but it should be noticed that the common and cosmopolitan jelly-fish, *Aurelia aurita,* passes through a juvenile fixed stage, attached to rock or seaweed.

THE WHALE AS A GREAT BUNDLE OF FITNESSES

The mammals of the open sea are the Cetaceans, giants like the Right Whale and the Sperm Whale, and small ones like dolphins and porpoises. All of them have such mastery of their medium that they must be ranked among the conquerors of the open sea. Let us think for a little of the whale as a great bundle of fitnesses, taking especially the

FIG. 4.—THE RIGHT WHALE, AN OPEN-SEA MAMMAL.
Note the Position of the Eye and of the Nostrils or Blow-holes. The Expired Air has carried up some Water.

Greenland or "right" whale, *right* from the whaler's point of view.

The whale is fish-like in shape; it has fore-fins like a fish, and it swims by means of its powerful fish-like tail. Yet, though we talk of whale "fishery," we all know that a whale is not a fish but a mammal, that is, a warm-blooded animal that breathes by lungs, and gives suck to its young. Naturalists have been able to show, from a study of the whale's own body and the bodies of its fossil relatives, that the ancestors of the whale were land mammals, and that, in taking to the sea, they lost many of the old characters of their race and acquired others more suited to their new mode of life.

The body is now fish-like because that is the shape most suitable for cleaving the water; the fore-limbs are flippers or paddles, yet within them "the whole inherited but greatly shortened skeleton of the mammalian forearm lies concealed." The hind-limbs were no longer of use, so they disappeared, but traces of their bones can still be found hidden beneath the blubber; the skin has lost its hair, except for a few very sensitive vibrissæ or whiskers about the mouth, but indications of hair can be seen in the developing young; and

under the skin there is a thick layer of fat or blubber, which serves the double purpose of keeping the body warm and lightening its weight in proportion to its size.

The whale catches the minute animals on which it feeds by swimming with its mouth open. But it must be able to breathe atmospheric air, not air dissolved in water as a fish does, and the nostrils, instead of being on the snout as in other mammals, are far back on the forehead, so that breathing can go on at the same time as swallowing. In short, as someone has said, if you took away from the whale all that is adaptation to its mode of life there would be very little of it left.

The teeth, when there are any, have changed in character, but in the "right" whale they disappear before birth, and have been replaced by long horny plates frayed at the ends, which hang down into the mouth. There are from three to four hundred of these plates, which form the valuable "whalebone" of commerce. The whale swims with open mouth through shoals of small animals like the sea-butterflies and water-fleas we have spoken of, and when it has secured a good mouthful it shuts its jaws and lets the water trickle out at the sides of

its mouth, while the whalebone plates act as a sieve and prevent the small animals from getting away. The stomach of a dead whale has been found to contain a mass of minute animals so thick that it could only be dug out with a spade.

The whale has no settled place of abode in the ocean, and its swimming powers enable it to make enormous journeys. Some whales "travel twice a year more than a quarter of the circumference of the globe, being in summer amid the Arctic snows, and in winter on the other side of the equator." They travel mainly in the wake of their food-supply, but as there is a great regularity in the occurrence of the smaller marine organisms, "their journeyings are in general as regular as if they were arranged according to the stars, and as if they took place along laid-out paths bounded on both sides."

On their journeyings the whales often form troops or "schools," consisting chiefly of females and young ones. The Greenland whale has usually only one young one at a time, which may be over three yards long at birth. The mother gives it suck for about a year, and is devotedly attached to it.

Unfortunately for the whale man long ago discovered the value to himself of the whalebone and the blubber, and the chase of the "right" whale has gone on for centuries. Even its mother-love has been turned to its disadvantage, for the inexperienced young one is easily caught, and the mother is absolutely careless of her own safety in her efforts to protect her offspring. Modern improvements in fishing vessels and apparatus have made the warfare a very unequal one, and this interesting animal is fast disappearing from the seas.

THE STORY OF THE STORM PETREL

No creature is more characteristic of the Open Sea than the Storm Petrel, for it rarely touches land except at the nesting-time. From the breeding-places, such as islets to the north and north-west of Scotland, they migrate in autumn to open waters and spend all the winter there. One of their many names, Mother Carey's Chickens, suggests that they are dear to the Holy Mother, who has the weak and storm-tossed in her keeping. As to the word petrel, it is supposed to refer to St. Peter's attempt to walk on the water, but it is more

likely that it points to the way in which the birds' feet go pitter-pattering as they touch the waves in their flight.

The Storm Petrel is a sooty-black bird, with a little white about the tail and under the wings, just over six inches in length, with long, somewhat swift-like wings well-suited for rapid flight, and with long legs, the meaning of which is obscure. Its relationships are with albatross, shearwater, fulmar, and the like, and in nowise with the gulls. This is shown by the fact that the horny bill is made up of numerous pieces (taking our thoughts back to reptiles' scales), by the curious drawing out of the two nostrils into a double-barrelled tube, by the single chalky-white egg with a few reddish-brown spots, by the very long sooty-ash down covering the nestling, and by many features going much deeper.

The Storm Petrel flies close to the waves with its web-feet touching now and then, and at other times it paddles about on the surface. Its food consists of small fishes, crustaceans, molluscs, and other Open-Sea animals. At the nesting-time it seems to be fond of morsels of sorrel! The crop contains a good deal of oil which the bird vomits up forcibly when taken

by surprise. It is given by both parents to the young. A captive Storm Petrel was fed for three months on oil alone. The amount of oil throughout the whole bird may be inferred from the fact that some islanders thread a wick through the dead body and use it as a lamp, "the excess of fat burning steadily until the whole is consumed."

The Storm Petrel's nest hardly deserves the name; it is never more than a little mattress of dry grass. The single egg is laid (about the end of June in Scotland) in a hole among the rocks or among loose stones, or in a burrow, which may be a rabbit's, or may be partly made by the bird's own exertions, though one would not think that tunnelling was much in its line. There is a heavy musky smell about the hole.

The parents seem to share in brooding, which lasts for about five weeks. During that time the birds are not seen coming or going, for they have become twilight birds, or dawn and dusk birds. We suppose one parent sits by day and the other by night. After the young bird is hatched out, it seems to be left to itself all the day long, while the parents collect oil for the heavy supper which their nestling makes and needs. It is not till the

PLATE VI.—THE STORM PETREL IN THE OPEN SEA.

autumn that the young bird is able to leave the hole and fend for itself,—a very prolonged infancy which shows us that the nesting-place must be well hidden. In this connection it should be noted that the parents fly straight into the hole when they come in from the sea and leave in the same direct way. They are sometimes quite noisy as they fly about at night, but they know the safety of darkness. They come and they go in dim light, at dusk and at dawn. Most elusive birds!

There is no doubt that the Storm Petrel belongs to a family of ancient birds, with a long pedigree going far back to some kinship with an extinct, giant, toothed Diver (Hesperornis of Cretaceous times). Like its relatives, such as the shearwaters, it has held its own by becoming highly specialised in its everyday habitat and also in its way of feeding on small surface animals of the Open Sea. It is very interesting to find among its relatives a Diving Petrel (Pelecanoides), remarkably but deceptively like a Little Auk, which has become a most expert diver, disappearing instantaneously, swimming swiftly with its wings under water, and emerging again *in flight*—a brilliant instance of the way in which survival is

secured by trying every niche of opportunity. It is the same with the Storm Petrel; it has survived by its originality.

OPEN-SEA INSECTS

A fine example of what we may call the adventurousness or insurgence of life is to be

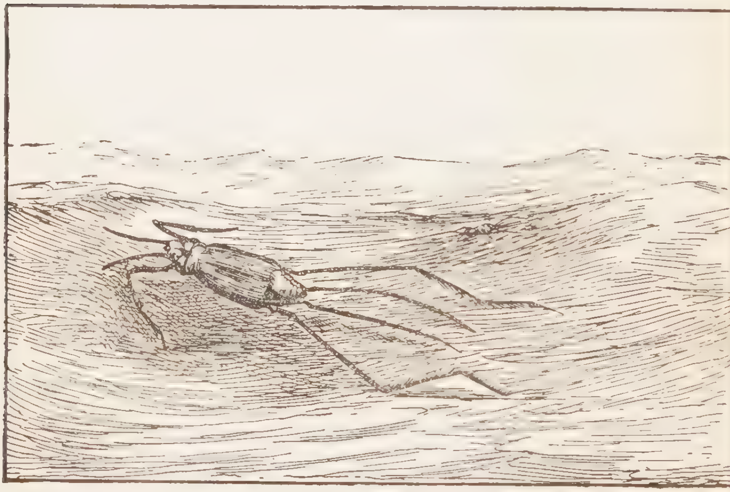


FIG. 5.—SEA-SKIMMER, HALOBATES.
An Insect that runs about on the Open Sea.

found in the family of sea-skimmers (Halobatidæ), wingless insects that run along the surface of the water, often a hundred miles from land. They are closely related to the

water-measurers (Hydrometridæ) which we see skating about on the surface of stagnant pools or even on quiet reaches of a stream, but if we had been asked for the unlikeliest haunt for an insect we should surely have said the open sea or the deep sea. The sea-skimmers appear to feed on floating dead animals, and when it is stormy they sink below the troubled waters—*how,* we do not know. Another interesting point is that the mother sea-skimmer has been seen carrying her eggs about with her after they have been laid.

TURTLES

Among the higher animals of the open sea must be reckoned some of the turtles; not the edible turtle, perhaps, for it is a vegetarian, and must, therefore, keep for the most part to the shore haunt, where seaweeds grow, but the carnivorous Hawksbill and the Loggerhead—the latter occasionally found on British coasts. There is also the rare Leathery or Lyre Turtle of most warm seas, a veritable pelagic giant. Dr. F. A. Lucas, Director of the American Museum of Natural History, tells us that he

has weighed some up to 940 lb. and measured some up to 7 feet in length. All these are doubtless the descendants of land tortoises, for they breathe dry air as terrestrial animals do, and they give away their secret in the fact that they all come to the shore to lay their eggs in the sand. Animals that have found a new kind of home usually go back to the old home to breed. Whales evade this law because the mother carries her young one for a long time before birth, so that when it is born it can swim for itself.

SEA-SNAKES AND SEA-SERPENTS

Turtles have their legs flattened into flippers,—the oars by which they swim; whales have their fore-limbs flattened into flippers, which are chiefly used in balancing, the propeller being the tail; snakes have no limbs, but it is interesting to find that the sea-snakes show a marked flattening in the tail region, and sometimes in the posterior part of the trunk as well. In all cases the meaning of the flattening is the same; it is an adaptation which secures a good grip of the water. The sea-snakes are mostly fish-eaters, and very

poisonous; they are common in the Indian Ocean; they are of course the descendants of land-snakes, and, as we have already mentioned, some of them at least come to the shore to bring forth their young.

The rock-record shows that there were once great sea-serpents, and he is a bold man who says he is sure there are none living to-day. We remember seeing in the Prince of Monaco's collection a great piece of a *scaly* cuttlefish. It came from the stomach of a sperm-whale, but no one has seen the animal. Unless the piece was a piece of the very last scaly cuttlefish, the animal is likely to be still represented in the seas. Perhaps there may be a giant sea-serpent too.

So many of those who go down to the sea in ships have seen sea-serpents that it is quite a reasonable inquiry to ask what kinds of sea-serpents they saw. One species certainly consists of the backs of a row of porpoises swimming quickly and showing at regular intervals on the surface. Another species consists of a long single-file of sea-fowl flying close to the surface. Another species is one of the large sharks, another is certainly a large cuttle, and another consists of the long lips

and tentacles of a huge jelly-fish swaying near the surface. Some jelly-fish have a disc a yard in diameter, and tentacles over 30 feet in length.

Another sea-serpent which our friend Mr. James Reid of Stonehaven went far to identify is almost certainly the Oar-fish or Ribbon-fish (Regalecus), a silvery fish flattened like an oar, sometimes over 20 feet in length. It is normally a deep-water fish, but it sometimes swims with an undulatory motion at the surface, and may, when attacked by some enemy, raise part of its body several feet out of the water.

FITNESSES OF THE OPEN-SEA DRIFTERS

It is plain that one of the chief requirements of an animal that lives in the open sea is, that it should be able to keep afloat. This is secured in many different ways. Thus there are various arrangements for increasing the surface of the body without greatly increasing the weight. Many minute surface creatures are practically unsinkable even though their skeleton is often made of flint. Their armature is produced into delicate processes or, in some cases, stalked discs like half dumb-bells, which

FIG. 6.—A REPRESENTATIVE JELLY-FISH OF THE OPEN SEA.
Note the four frilled Lips and the Tentacles round the Margin of the Disc.

give them a big hold of the water. Some larval fishes, like those of the Angler, have long flexible ribbons floating out like decorations; and these probably help in flotation (Fig. 7).

Some of the drifters have bodies large in size, but with so much sea-water in them that they cannot sink. They have almost the same specific gravity as the water. If we look into the sea from a boat we often see the common jelly-fish (Aurelia) opening and shutting its umbrella or disc a little below the surface. It looks quite large in the water, and for a time after it has been cast upon the shore by the tide. But a few hours later it has shrivelled up into a very papery heap indeed. Its body is made up of more than ninety per cent. of water, and when that has evaporated there is very little animal matter left. A great many drifting animals have this swollen, watery tissue.

The presence of fat or oil serves the same purpose of lessening the body weight, and many of the smaller animals and some pelagic eggs have this character in common with the actively moving animals like the whales, porpoises, and many fishes.

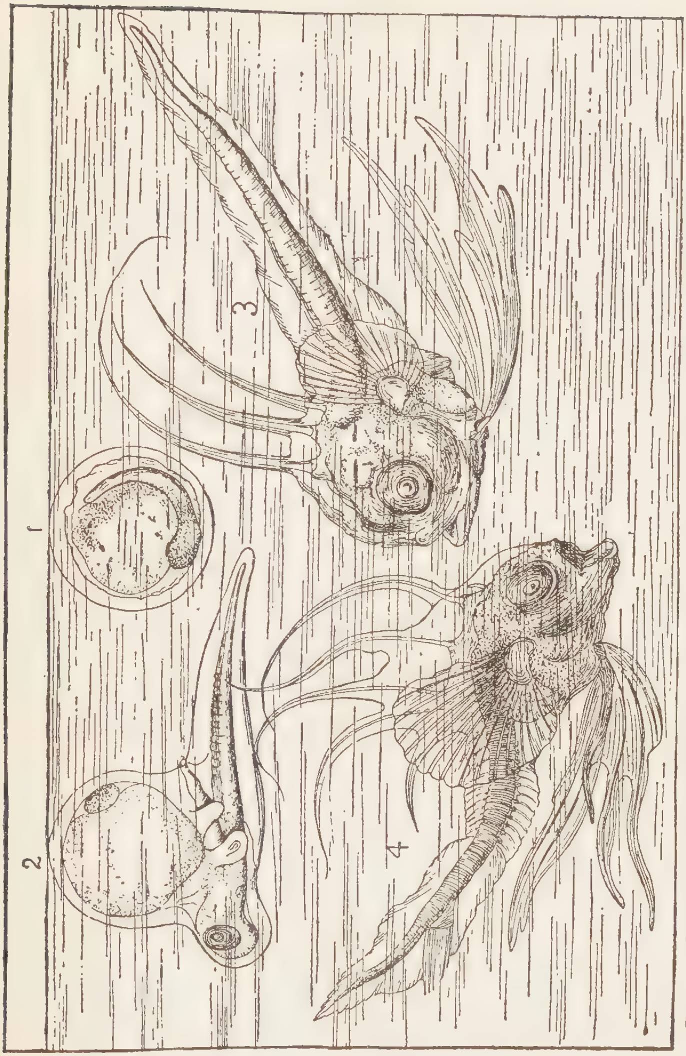


FIG. 7.—EARLY STAGES IN THE LIFE-HISTORY OF THE ANGLER OR FISHING FROG. (AFTER BOWMAN.)
1. A developing Egg floating at the surface of the Sea. 2. A newly hatched Larva, floating upside down, below its Yolk-sac. 3 and 4. Later free-swimming Stages with remarkable Streamers which help in Flotation.

Some of the drifters, instead of having the whole body made light, have some special part of it adapted to serve the same end. We can best understand these adaptations if we compare a pelagic animal with one of its own relatives which lives under different conditions. For instance, in many parts of the ocean, there are often to be seen swarms of what are popularly called "sea-butterflies," or, not quite so prettily but more accurately, "winged snails." These little animals are Gasteropod Molluscs, and some of them—for there are many different kinds—have shells, in one case spirally twisted like that of the snail. But whatever be the form of the shell it is always small and light so as not to add much weight to the body. In place of the fleshy walking "foot" of so many land and shore snails the sea-butterflies have "wings," not in the least like those of a butterfly, but simply outstretched lobes or leaves of muscle which buoy them up and catch the wind so that they seem to be skimming lightly over the surface of the water. Most of the sea-butterflies inhabit warm latitudes, but one kind, with a shell no larger than a pin-head, occurs in such numbers in the Arctic

seas that the fishermen call it "whale-food."

Sometimes the special device for keeping afloat is just some transformation of, or addition to, the animal's usual organs of locomotion. Many of the tiny crustaceans, known as copepods or "water fleas," have on the jointed legs that they possess, in common with their larger relatives—lobsters, shrimps, and the like—thin projecting spines, each bearing smaller spines, all so delicate and so much

FIG. 8.—AN OPEN-SEA "WATER FLEA."
Showing Delicate Processes which make Flotation easy.

interlaced that the whole structure has the appearance of a feather. But that is not enough to keep the copepod afloat; it uses the long antennæ or feelers on its head to give a kind of rowing stroke. It does this for

several successive strokes, and then stops for a little. "During the period of rest the body sinks slowly, sometimes imperceptibly, but never so much that it cannot recover its position in the water after the first few strokes."

THE STORY OF THE FLOATING BARNACLE

Barnacles are strange crustaceans which give up free-swimming when they are very young and attach themselves to drifting logs or the keels of ships. Even a sea-snake has been seen with a big bunch on its tail, and some of the unstalked acorn-shells, which are second cousins of the stalked barnacles, are found attached to the skin of whales.

The newly hatched barnacle is like the newly hatched larva of many of the lower crustaceans. It has a body a little like half a pear cut lengthwise and about the size of a small pinhead. It has a median eye on the top of its head and three pairs of swimming appendages. It is called a Nauplius, but that is neither here nor there. It feeds and grows and moults, changing its form into what is called a Cyprid larva. This seems to become

exhausted, for it attaches itself by its head to a floating log, and the front of the head grows

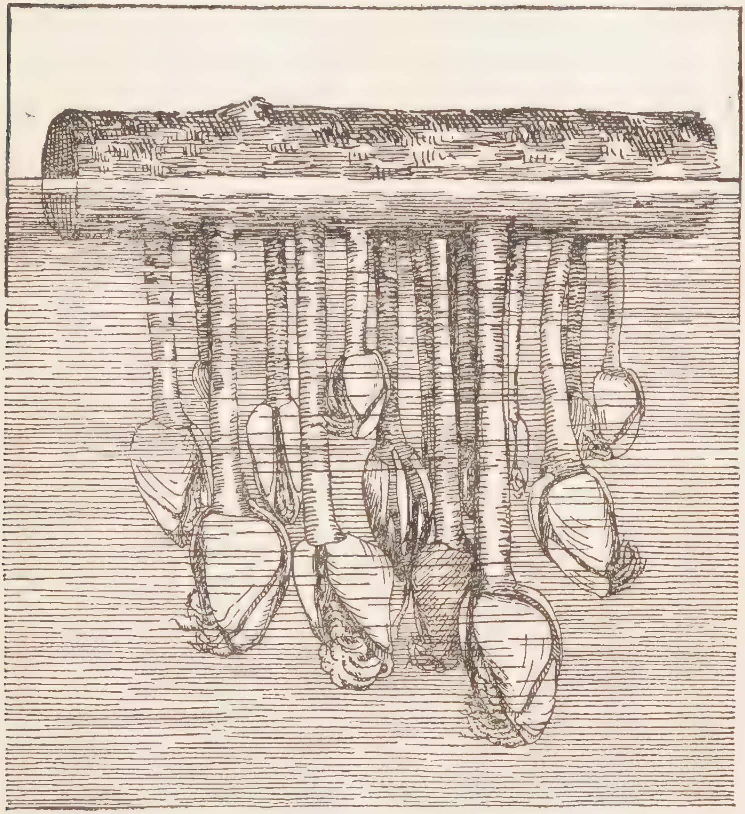


Fig. 9.—A Cluster of Barnacles (Lepas anatifera).
Hanging from a Floating Log. Note the Curled Feet projecting from the 5-valved Shell.

into a long elastic stalk, which bears the main part of the body on its free end. From

between the five valves of a shell that protects the main body of the barnacle, six pairs of feather-like limbs can be protruded, which waft microscopic organisms and particles into the mouth. So much for the ordinary ship-

FIG. 10.

A. THE FLOATING BARNACLE, with a self-made Buoy on the Stalk between it and a piece of Floating Seaweed.

B. A COMMON BARNACLE.

barnacle, hundreds of which may sometimes be found attached to a log which is tossed up on the beach by a storm after having drifted, it may be, across the Atlantic.

The particular kind of barnacle which we

are calling the Floating Barnacle (*Lepas fascicularis*) often fastens itself to a small piece of detached seaweed—it may be to a feather or a wooden match. Its shell-valves are very lightly built, with little lime in them, and this is well suited for a creature that fixes itself to a light float. But in spite of its lightness of shell, the Floating Barnacle often becomes, as it grows bigger, too heavy for its float, and begins to drag it below the surface. What then does the creature do—we wish we understood it better—but make a somewhat gelatinous, roundish buoy containing bubbles of gas. This is secreted at the lower end of the attaching stalk, just above the main body, and the self-made buoy enables the barnacle to continue floating at the surface. This is a very pretty adaptation (Fig. 10).

HUNGER AND LOVE IN THE OPEN SEA

Hunger is much in evidence in the open sea. The baleen whale rushes through the water, engulfing countless open-sea creatures in the huge cavern of its mouth. They are caught on the frayed edges of the whalebone plates which hang downwards from the palate. If

we look into the mouth of a good-natured horse when it yawns we see ridges crossing the palate; if these ridges were to grow into long vertical plates and become horny they would correspond to whalebone plates. Every now and then the whale raises its tongue and brushes a myriad of creatures towards the back of the mouth, where they are swallowed. It is interesting that this giant should feed on such dainty morsels. The reason why it does not drown as it rushes open-mouthed through the water is that it shunts its glottis (the entrance to the windpipe) forward to embrace the posterior end of the nasal passage, so that no water goes down the wrong way!

But there is love as well as hunger in the open sea, and no better example could be found than the Paper Nautilus or Argonaut. This is a kind of cuttlefish which floats on the surface, and is not to be confused with the Pearly Nautilus which belongs rather to the shore haunt. The most remarkable thing about the Argonaut is that the female makes, for the protection of its eggs and young ones, what may well be called the most beautiful cradle in the world. It is not a house to live in like the chambered shell of the Pearly Nautilus; it is a

cradle made by the female only. Moreover, the delicate cradle is made as a secretion from two of the "arms," not as a secretion from the "mantle," the fold of skin which manufactures the shell of all other Molluscs.

Another pretty case is the egg-raft of the mollusc called Ianthina. This open-sea Gasteropod has a lightly built shell of a fine violet colour, and when the time for egg-laying comes a bubbly float is made in which the eggs are embedded, and this is towed about by the parent as it swims.

THE OPEN SEA AS A NURSERY

Another big fact must be included in our picture of the open sea—that it is the nursery for the young stages of many shore-animals. Delicate young stages which could not survive for an hour in the rough-and-tumble conditions of the shore are nurtured safely in the spaciousness and easy-going uniformity of the open sea. There is no better example than the common Shore-Crab (*Carcinus mænas*). The developing eggs are carried about by the mother under the shelter of her tail. Out of the eggs come dainty pinhead-like, free-swim-

ming larvæ, called zoeæ, marked by a spine rising vertically above the back, and by a tail sticking out at an angle to the rest of the body. These larvæ are swept out into the safety of the open water, and they swim about near the surface. They feed, they grow, they moult, and another form of larva results. This does the same, and a Megalops larva results, which is beginning to be like a crab. It has lost the spine; it has stalked eyes; it has got its full complement of legs. Now this Megalops bends its tail forwards and upwards underneath the anterior part of the body (the *cephalothorax*); it ceases to be a free-swimmer; it sinks to the floor of the sea, and creeps up the slope to its birthplace on the shore—a little crab about half the size of the nail of our little finger.

There is an interesting illustration of "The Balance of Nature" in this connection. It seems that the shore-waters are, on the average, richer in Plankton than any other waters, the reason being that they are always receiving abundant supplies of valuable salts brought down from inland by rivers and streams. So the shore-waters serve as a sort of nursery of minute creatures that get swept out to sea to

form the "floating sea-meadows." Thus the Shore helps the Open Sea. On the other hand, as we have seen, there are many shore-animals which depend upon the Open Sea, for it is the kindly cradle of their fragile youth.

CHAPTER III

THE GREAT DEEPS

The *Challenger* Expedition—The Deep Deep Sea—Great Pressure—Very Cold—Very Dark—Very Calm and Silent—Monotony—No Depth Limit to Life—No Plants in the Deep Sea—No Rottenness—A Representative Fauna—Fitnesses of Deep-sea Animals—Puzzle of Phosphorescence—Big Eyes and Little Eyes—Origin of Deep-sea Animals—Hunger and Love in the Deep Sea—Retrospect.

TO our forefathers the depths of the sea were as unknown and as mysterious as fairyland. Very early, indeed, fishermen had begun to explore the surface-waters, and had forced them increasingly to contribute of their abundance to their support, but the life of the great depths was absolutely unknown, though imagination peopled them with strange forms. As late as the sixteenth century a famous book by Conrad Gesner contained, mixed up with illustrations of real animals, pictures of mermen and mermaidens, tritons, dragons, sea-devils, sea-bishops, and other fabled monsters.

Plate VII.—The Floor of the Deep Sea.

Showing a dredge being dragged along, three strange abyssal fishes, a graceful yard-high Umbellula, with a tassel of Polyps at the top and the base fixed in the ooze.

By the beginning of the nineteenth century imagination was being corrected by scientific investigation, and people were becoming disinclined to believe more than they could see. Apparatus for research was still very imperfect, and we find a great English naturalist, Edward Forbes, in 1850, declaring his belief that there are no living animals below 300 fathoms. And this in spite of the fact that in 1818 Sir John Ross dredged a Brittle-Star (Astrophyton) from 800 to 1000 fathoms.

Even when animals were brought up in the net from considerable depths, it was objected that there could be no certainty that these were not caught on the way up. But that living creatures existed at much greater depths than had been supposed was suddenly proved beyond all doubt by an accident. A submarine cable broke, and when the two ends were fished up for repair, they were found encrusted with several different kinds of animals. This discovery gave a great impetus to investigation. It was too costly for private enterprise, but the Governments of various countries, Britain, France, Norway, Italy, and the United States, took the matter in hand, and expedition after expedition was sent out, with special equip-

ment for studying the physical conditions of the great depths, and obtaining specimens of the animals that inhabit them.

THE "CHALLENGER" EXPEDITION

The first great expedition was that of the *Challenger* (1872-76), which may be called a Columbus voyage, since it practically discovered a New World—the world of the Deep Sea. During three and a half years the *Challenger* circumnavigated the globe, cruising over 68,900 nautical miles. The naturalist in charge was Sir Wyville Thomson, and the staff included Mr. John Murray (the late Sir John Murray) and Mr. J. Y. Buchanan. Reaching down with the long arm of the dredge, the explorers raised treasures from over 300 stations. The results of this great expedition were published under Sir John Murray's editorship in fifty quarto volumes. These form the firm foundations of oceanography—the science of the sea.

It was at first expected that many of the deep-sea animals would be quite different from those living in shallower waters, and would resemble older types now known only as fossils, but with few exceptions this did not prove to

be the case. The deep-sea animals have been found on the whole to be very similar to others of the same families living on the shore or near the shore elsewhere, with, however, certain well-marked differences, which make them better fitted for life in their actual surroundings.

Thanks to the efforts of the different exploring expeditions and to the published records of their work, we have now some very definite ideas of the conditions of life at the bottom of the sea, and of the ways in which animals are adapted to them.

Every expedition that has been sent out has carried more and more perfected apparatus for exploring the great depths. It has been found possible to bring up specimens of the lowest layer of the water, and of the actual sea-floor itself, as well as of the animals that lived there. Thermometers have been devised for registering the temperature, and instruments for measuring the pressure at different levels.

THE DEEP DEEP SEA

By the deep sea naturalists mean practically the floor of the deep parts of the sea and the layers of dark water near the floor. Compara-

tively little is known of the vast zones between the end of the light's reach and the floor of the sea, so that, although they are included in the idea of the Deep Sea, we may confine ourselves in this study to the floor of the great abysses. This is one of the largest haunts of life, occupying about 100 million square miles, *i.e.* more than a half of the whole earth's surface; and it is the strangest. It is not difficult to get comparatively near it, within a stone's-throw of it, for we can toss a pebble into it from the deck of a liner; but no one has ever seen it. It is a bourne from which no traveller can return. Yet we know a great deal about it, thanks to the patience of explorers.

The world of the deep sea is very deep, for the average depth of the ocean is $2\frac{1}{2}$ miles; and, as vast areas are comparatively shallow, there must be other parts extraordinarily deep. Just as the earth's crust has been buckled into great mountains (the true mountains, not those that are formed by the unequal weathering of plateaux), so it is dimpled down into depressions. The very deep holes are called "deeps"; and the so-called "Challenger deep" in the North-West Pacific is nearly 6 miles in depth, namely, 5269 fathoms. If one

could throw Mount Everest into this "deep," the mountain would be swallowed up, with 2600 feet to spare. The "Swire deep," off Mindanoa, is actually a little over 6 miles in depth.

GREAT PRESSURE

In deep water there is necessarily great pressure, because of the immense weight of water. At 2500 fathoms it is 2½ tons on the square inch—an unendurable pressure, if it were felt. It is twenty-five times greater than the pressure exerted by the steam on the piston of our best railway locomotives. The general reason why the pressure is not felt is that the bodies and tissues of the animals are permeated by the water. If a ship's hawser is sunk to a great depth, it is squeezed to less than the diameter of one's wrist. If a piece of wood is weighted and sunk to a great depth, it is so much compressed that it will no longer float when brought to the surface again. But if a delicate glass vessel with holes all over be lowered it is not broken, for the water goes through and through it. In a general way, this is true of the deep-sea animals. But this is not the whole truth.

It has happened repeatedly that a closed glass thermometer sent down inside a metal tube has been brought up again powdered to a fine dust. In one experiment made on board the *Challenger*, a thick glass tube full of air was sealed at both ends, wrapped in flannel, and put inside a copper tube with holes at each end. This was lowered to a depth of 2000 fathoms, and was then drawn up again. Not only was the glass tube powdered, but the side of the copper case was crushed inwards by the pressure. Before the empty space caused by the shivering of the glass tube could be filled with water, the side of the copper case was stove in—an "implosion," as one of the explorers said, had occurred.

Because of the pressure, deep-sea animals are "liable to an accident to which no other animal in the world is liable—that of tumbling *up*." Most fishes have a silvery swim-bladder or air-bladder, which contains gas and enables the fish to accommodate itself to different depths. But this accommodation must take place very gradually, and if a deep-sea fish, in chasing its prey, rises too high or too suddenly, its swim-bladder expands so much that it cannot be controlled by the muscles.

The fish is therefore unable to go down to the bottom again, but rises helplessly, and more and more rapidly, until it reaches the surface, usually dead, with its body greatly distended, and sometimes even split open.

VERY COLD

The deep sea is a very cold haunt, for the sun's heat is practically lost at about 150 fathoms; and there is a continual sinking down of cold water, *rich in oxygen,* from the Poles, especially from the South. Throughout the year there is little variation in the abyssal temperature, which remains at about 28°–34° Fahrenheit, a little on each side of the freezing-point of fresh water. Eternal winter reigns. There are cleverly made thermometers for taking the temperature of the abysses; thus, after the well-protected thermometer has been down for a while, a metal "messenger" is sent spinning down the wire, which hits a spring and turns the thermometer upside down, so that it cannot change on the way up. In a similar way water-bottles that collect samples of the water at various depths can be automatically closed at any point.

VERY DARK

Very sensitive bromo-gelatine plates, automatically exposed and closed again at a depth of 500 fathoms—about half a mile—show that some rays of light reach that depth. For practical purposes, however, it is dark at 250 fathoms. Thus the deep sea is a world of dreadful night, and the utterness of the darkness must be almost intensified, one would think, by the fitful gleams of "phosphorescent" light given forth by various deep-sea animals, both sedentary and wandering. Perhaps it is like the very badly lighted suburbs of a big town; perhaps it is like a moor on a very dark night, with only a few stars overhead.

VERY CALM AND SILENT

The deep sea is a place of silence and calm, for no sound can reach the depths, and the severest storms are comparatively shallow in their grip. There are no swift currents, but at most a gentle flow over the beds of ooze. What is this "ooze"? Over vast tracts of the ocean-floor there is an accumulation of minute particles, as fine as dust, varying in character

from place to place. This is ooze. One kind consists mainly of the beautiful lime-shells of certain types of chalk-forming animals or Foraminifera (Globigerinids) which live on the surface of the sea. When these animals are killed the shells sink to form Globigerina deposit, which is very abundant on some parts of the floor of the Atlantic. Similarly there is Radiolarian ooze, consisting chiefly of the beautiful flint-shells belonging to another set of pelagic animals. Pteropod ooze consists mainly of the remains of the delicate shells of certain "sea-butterflies," and Diatom ooze consists mainly of the siliceous shells of these very simple pelagic plants. Then there is what is called "Red Clay," though it is neither red nor clay, a fine powdery stuff made by the final disintegration of mineral materials—all sorts of things reduced to their lowest terms. In a general way we must think of the ooze as due to the settling down of "the dust of the sea." In its softer forms it has been described as "like butter in summer." If there were rapid currents the ooze would be swept about and make life impossible, but it is well suited for a world of calm. When we think of the ooze we can readily under-

stand why many of the sedentary abyssal animals, such as the Glass-Rope-Sponge, are fixed by long stalks, and why many of the wandering abyssal animals, such as crabs and sea-spiders, have very lanky legs, for walking delicately on the treacherous surface

MONOTONY

The Deep Sea must be the most monotonous place in the world. There is no scenery, but a succession of dreary undulations like those of sand-dunes. Only here and there are there ridges like water-sheds or volcanic cones rising to the surface, perhaps to form the foundations of sunlit coral islands. Moreover, everything is so continuous—eternal winter, eternal night, eternal silence. What an eerie picture this—a deep, dark, cold, calm, silent, monotonous world.

NO DEPTH-LIMIT TO LIFE

What of the life of the great deeps? The biggest fact is that there is no "deep" too deep for life. There are more animals at the more moderate depths; there are more ani-

PLATE VIII.—DEEP SEA NEAR SHORE.

In the shallow shore area, note Crab, Star-fish, Sea Anemone, Seaweed. In the great depth, note a fish with enormous gape, a young fish with long-stalked eyes, two fixed Feather-Stars, an Umbellula a yard high, with the base of its stalk embedded in the ooze.

mals on the lime-ooze than on the "red-clay" mud-ooze; and we do not know much about the thinly peopled miles of water between the limit of the light, say half a mile at the most, and the floor itself. But the big fact is that wherever the long arm of the dredge has reached down it has brought up living creatures. It is astounding to read that on the "Michael Sars" exploration, the late Sir John Murray and Dr. Johan Hjort worked an otter-trawl with a spread of 50 feet at a depth of 2820 fathoms, which is over 3 miles!

NO PLANTS IN THE DEEP SEA

There are, of course, no plants in the great depths, except the resting-stages of a few Algæ that have sunk down from the surface. We say, "of course," because all ordinary plants, possessing chlorophyll (disguised by other colours in many seaweeds), require light if they are to live. This raises an interesting question, for if there are no plants it seems at first sight as if all the abyssal animals must be eating one another, which is absurd, as Euclid used to say. No doubt the deep-sea fish eats the deep-sea crustacean, and the deep-sea crustacean

the deep-sea worm, and the worm—something else; but that cannot be the whole story.

What then is the basis of the food-supply of the deep-sea animals? The first part of the answer to this question is, that although there are no living plants there is often plenty of dead vegetable matter. Some of this is washed out from the coastal belt and from the mouths of rivers, for even at great depths, far away from the coast, animals have been fished up with their stomachs full of remains of sea-grass and even of terrestrial plants. But the greater part of it comes from the surface, and consists of the remains of the minute algæ or marine plants which, as we have seen, are so abundant there. These minute particles of vegetable matter form the food of many of the smaller deep-sea creatures.

Secondly, we must remember that dead animal matter is continually sinking down from the surface. This consists of minute animals that have been killed by vicissitudes of temperature and the like, or of particles from the decomposing bodies of surface animals which have either fed directly upon plants, or have been able to elaborate their own food in the same way as plants.

In rare cases it may be that organic matter in the water is simply absorbed by the animal's body without any direct "feeding" at all, or it may be wafted into the mouth by tentacles and cilia, or it may simply sink into capacious open mouths, as in the case of abyssal sea-anemones. But many of the animals living on the ocean-floor are "mud-eaters," and as the rich "ooze" passes through their food-canal the organic matter it contains is digested. The same thing happens in the case of the common earthworm as it eats its way through the soil, or in the case of the lobworms on the sandy beach.

It may be asked how we know what deep-sea animals eat since we cannot of course actually see what takes place in the dark abysses. The answer is that the contents of the food-canal can be studied in animals dredged up, and also that we can carefully compare those that are brought up in the dredge with their near relatives living under different conditions, and try to make out what the differences between them may mean.

Thus it is certain that many of the fishes at the bottom of the sea are voracious flesh-eaters. Some of them are of the usual wedge-shape, with long tails, but a great many are quite

different. They have enormous heads with strong jaws and teeth, and very large round bodies, so that they look as if they were "nothing but a mouth and a stomach." Sometimes the lower part of the skin of the body is so loose that it can stretch to an enormous extent, and more than once a fish has been dredged up containing within it, still undigested, another as big as, if not bigger, than itself!

Before we leave the question of food, we should be clear in regard to two things—first, that the absence of living plants in the Deep Sea is bound to make the animal's struggle for existence very keen; and, second, that what count for most are not the bodies of big animals that occasionally sink to the bottom, but the minute creatures which are ceaselessly sinking. It is rather a pretty picture—the ceaseless rain of dead animalcules sinking through the miles of water like snowflakes on a quiet winter evening.

NO ROTTENNESS

We are accustomed to think of Bacteria as practically omnipresent, playing many a rôle in the drama of life, now helping and again

hindering. There are many Bacteria in the surface-waters of the sea, where they help in the circulation of matter, but there do not seem to be any in the great depths. That means that there is no rotting, for there is no rotting without Bacteria. If a dead whale sinks to the floor of the sea, with its flesh compacted together like pressed beef, it is nibbled to fragments by crustaceans and other scavengers, and all of it is devoured or dissolved, save the cowrie-like ear-bones which are almost as hard as stone. But the microscopic atomies in their never-ending shower count for much more than the carcases of whales.

A REPRESENTATIVE FAUNA

It is interesting to find that the assemblage of animals on the floor of the Deep Sea is not a picked one, but very representative. There are many simple microscopic creatures—Foraminifers and Radiolarians; many horny and flinty (but no calcareous) sponges; sea-anemones and corals; worms of many kinds in abundance; star-fishes, brittle-stars, sea-urchins, sea-cucumbers, and many sea-lilies; numerous crustaceans and quaint creatures

called sea-spiders, whose precise relationships are uncertain; lamp-shells and colonies related to the sea-mat; all sorts of molluscs—bivalves, snails, and cuttles; the degenerate sea-squirts, some on long stalks; and numerous strange fishes. Here the list ends—for we dare not include sea-serpents in the *abyssal* fauna at least.

Walt Whitman's famous picture, "The World below the Brine," refers not so much to the Deep Sea as to the bottom of the sea within the shore-area in the wide sense. But it is incomparably fine.

> "Forests at the bottom of the sea, the branches and leaves,
> Sea-lettuce, vast lichens, strange flowers and seeds, the thick tangle, the openings, and the pink turf,
> Different colours, pale grey and green, purple, white, and gold, the play of the light through the water,
> Dumb swimmers there among the rocks, coral, gluten, grass, rushes, and the aliment of the swimmers,
> Sluggish existences grazing there or suspended close to the bottom,
> Sight in these ocean depths, wars, pursuits, tribes breathing that thick-breathing air, as so many do."

FITNESSES OF DEEP-SEA ANIMALS

Many of the fixed animals of the great depths have long stalks which raise the im-

FIG. 11.—FEATHER-STARS OR SEA-LILIES (CRINOIDS).
Growing from the Floor of the Deep Sea.

portant part of the body out of the treacherous, smothering ooze. This is very well illustrated by the sea-lilies or Crinoids, distant relatives of star-fishes, which occur in great beds like daffodils by the lake-side. Another very good example is to be found in the Umbellulas, near relatives of the sea-pens, where the stalk is sometimes a yard long, and bears at the top a pendent cluster of polyps, often of a beautiful blue colour.

As intelligible as the long stalks of many sedentary animals are the long legs of many of the wanderers. Some of the deep-sea prawns are the lankiest animals in existence. Some of the sea-spiders move about on long legs like stilts. This is well suited for prowling about on the surface of the abyssal ooze.

Then there is the exquisite tactility of many. In a world of darkness, where sight counts for little, touch becomes the important sense. Some of the deep-sea prawns have feelers several times longer than their body. One crustacean has antennæ fully a yard long. The deep-water fish called Lamprotoxus, captured off the west coast of Ireland, has a barbule several times its own length, and yet this long probing feeler is just an exaggeration of the little

tactile organ seen hanging down for about an inch from the front of the cod's lower jaw.

Another fitness is the delicate build of the body—such as we see in Venus's Flower Basket (Euplectella), whose flinty skeleton rises like a fairy palace from the floor of the deep sea. When the sponge is living, the beauty of the skeleton is hidden by the tissues, and the significance of the skeleton to the animal is that it forms a scaffolding for lifting a fairly big body—sometimes about 2 feet high—off the floor of the sea. The scaffolding is so delicate that the weight of a child's hand crushes it, and yet it is more effective than a solid bone would be to resist the enormous pressure of the water—many tons on the square inch. It circumvents the pressure, for when the water gets through and through an animal the pressure inside and the pressure outside are equal. The same applies to the Glass-Rope-Sponge (Hyalonema), which is raised on a long stalk of flint fibres, always bound together by a colony of anemones. The theory of the adaptation to outside pressure becomes more difficult when we pass to animals with a body-cavity, a food-canal, blood-vessels, and so on, but the general theory re-

mains the same. It is interesting to find that the bones of some deep-sea fishes are so lightly built that one can run a needle through them without breaking the point.

It is not asserted that substantial skeletons do not likewise occur in the deep waters. That is another way of solving the problem, which some of the deep-sea corals illustrate. But the usual way out of the difficulty is what we have tried to explain: the pressure is circumvented by making the whole body very permeable.

PUZZLE OF PHOSPHORESCENCE

While there are many features of deep-sea animals which we can interpret as well fitted to the peculiar conditions, there are others which are puzzling. One of these is the common occurrence of light-production. It is difficult to get rid of the word "phosphorescence" as a name for the light given out by some living creatures—both plants and animals. But whatever be the nature of the light given out by fire-flies and glow-worms, fire-flames and sea-pens, it is *not* phosphorescence. It might be called chemi-luminescence, for it is a by-

play of certain chemical processes in which oxidation plays a central part. Incandescence is light given off under the influence of great heat, but animal luminescence is a "cold light" with little or nothing in the way of heat rays. In the cases which have been most studied, the boring bivalve called Pholas, the luminous beetles called fire-flies, and the luminous water-flea called Cypridina, there are always two substances involved in the animal light. There is a substance called *luciferin,* which is oxidised, and there is a substance called *luciferase,* which acts on its neighbour like a ferment. Sometimes the light is given out by a stuff manufactured in scattered or definitely arranged glands, and then it may stream into the water, or the whole clammy surface of the animal may sparkle. In other cases, the light is only seen inside special organs, the luminous organs, which are often very complex and curiously like eyes. It is strange that organs which produce light should sometimes show a very striking resemblance to organs which detect light, namely, eyes. If you say that it is not so very strange, for the cat's eyes shine in the dark, you are perhaps not altogether wrong, for although the shining of the cat's eyes is

just the reflection of scant gleams of light and is never seen in total darkness—when animal light is best seen—there is something quite useful in the comparison, for the luminous organs have often reflectors not very different from the reflector in the back of the cat's eye.

In any case, "animal light" is common in the deep sea, both in fixed and wandering creatures. The light-giving stuff or secretion, which remains luminescent after the animal is dead, often oozes out on the general surface, as in sea-pens, and may trail into the water. In its finer forms, in fishes and crustaceans, it shines out from complicated lanterns, the special luminous organs.

The Marquis de Folin, who was with one of the great French expeditions, describes the surprise and delight of the naturalists on board the exploring vessel when they first saw a deep-sea dredge brought up in darkness. The dredge contained many coral animals, shrub-like in form, which threw off "flashes of light, beside which the twenty torches used for working by were pale." Some of the corals were carried into the laboratory, where the lights were put out. "There was a moment of magic, the most marvellous spectacle that

FIG. 12.—SEA-PENS AND UMBELLULAS.
Embedded in the Ooze.

ever was given to man to admire. Every point of the chief branches and twigs of the coral Isis threw out brilliant jets of fire, now paling, now reviving again, to pass from violet to purple, from red to orange, from bluish to different tones of green, and sometimes to the white of over-heated iron. The pervading colour, however, was greenish; the others appeared only in transient flashes, and melted into the green again. Minute by minute the glory lessened, as the animals died, and at the end of a quarter of an hour they were all like dead and withered branches." But while they were at their best "one could read by their light the finest print in a newspaper at a distance of 6 yards."

In the case just described, the light was apparently given off from the whole of the living matter covering the limy skeleton, but very often it comes from particular spots or "light organs." One cuttlefish has about twenty of these luminous spots, "like gleaming jewels, ultra-marine, ruby-red, sky-blue, and silvery," and another has minute light-giving points dotted all over its body.

Fishes often have these light-giving spots, and we are told of one fish which has two

large luminous plates just under its eyes. One of these gives off red light and the other green, and from the arrangement of the muscles connected with them, it is thought that the fish has control over them, and can turn on its lamps at will, to warn off its enemies or to aid it in the search for its prey!

"Very strange indeed would be the appearance of these animals if we could see them in the deep! In the absolute darkness of the abyss they would appear as ghostly, silver-blue shapes, glimmering like an electric lamp through dense fog on a dark, moonless night. Of all the characters of deep-sea fishes this almost universal phosphorescence is the strangest."

Another puzzle may be found in the fact that many deep-sea animals are brightly coloured. Bright red is common, for instance, in crustaceans, star-fishes, and sea-anemones. There is very little in the way of pattern, but there is not a little colour. What can be the meaning of colour in a world of darkness? It is highly probable that the colours as such have no significance in the life of these deep-sea animals, that they are simply the useless by-products of some of the fundamental proc-

esses that go on in the body. If this is so, they have their counterpart in the brilliant colours of the withering leaves in autumn. For these colours, as colours, are of no use to the trees.

BIG EYES AND LITTLE EYES

Another puzzle of the deep sea is the occurrence of fishes with big eyes and of others with little eyes. If the fishes were all small-eyed or approaching blindness, it would be easy to say that in a world of darkness they were gradually losing their sight, for we know that gold-fishes kept in absolute darkness for three years become blind, actually losing the perceiving elements called rods and cones in the retina of the eye. But what is to be made of the occurrence of big-eyed and small-eyed fishes in the same conditions? Perhaps it might be said that the small-eyed forms have been longest in the abysses, and therefore show greater degeneration of the eye. But this cannot be the whole answer, for in many cases the eyes are unnaturally large—so large that they occupy about a fifth of each side of the head. Sometimes they have become what are called telescope-eyes, projecting far forward

on a cylindrical stalk, so that they are fitted for making the most of a dim light.

Two answers to the question are possible. The first is, that though the animals with large eyes have been dredged up from the great depths, and probably spend most of their time there, they may sometimes migrate far enough upwards to come within the sun's influence, and it is only if the eyes are never used at all that they tend to dwindle away.

The second answer is, that though there is no daylight, there is some light from luminescent animals. Perhaps it is this uncertain light which the big eyes use.

Perhaps one of the biggest puzzles is that the ordinary activities of life, such as digestion and breathing, seem to go on quite smoothly in the great deeps, although the conditions of life are so very different from those to which the shallow-water relatives of the abyssal animals are accustomed.

ORIGIN OF DEEP-SEA ANIMALS

Where did the deep-sea animals come from? This is a good question, but we do not yet know enough to be able to answer it as we

should like. In a general way the answer is that most of the deep-sea animals are derived from shore-animals that migrated gradually —following the drifting food and sea-dust— down the slope into the abysses. There are no *very* ancient types in the Deep Sea; there are much more old-fashioned creatures in shallow water. It does not seem likely that any of the present-day deep-sea animals were established there before the Triassic Age. Many are probably much more recent.

HUNGER AND LOVE IN THE DEEP SEA

There can be no doubt that there is often very strict rationing in the Deep Sea. This is unmistakably shown by the enormous gape in many of the fishes, by the webbing of the arms in some cuttlefish to form a capacious funnel, by the big, soft mouth of sea-anemones, and by many other hints of hunger.

But the other note is also sounded. The *Challenger* explorers found a sea-cucumber with its fully formed young ones attached to the skin all along the upper surface. There are numerous expressions of a kind of parental care among brittle-stars, especially in

the Antarctic. The male sea-spiders from the deep sea, like those from shallow seas, carry the bunches of eggs attached to their limbs. It is also interesting to find that some animals, whose seashore representatives liberate eggs, bring forth embryos in the Deep Sea. This is probably an adaptation which counteracts the risk of the passive eggs being smothered in ooze.

RETROSPECT

Let us now gather together briefly what we have learned, and try to make a mind-picture of the depths of the ocean.

The average depth is 2½ miles, but there are "deeps" of over 6 miles, so that the highest mountain in the world, if thrown in, would be far below the surface of the water.

It is very cold; it is absolutely soundless; it is calm, and quite dark, save for the weird blue-green light radiating from the corals fixed in the mud, or from the luminous spots of the animals slowly moving in and out among these "perpetual light-houses." Starfishes, sea-urchins, sea-cucumbers, many kinds

of molluscs, many worms, and hosts of other animals lie buried in the mud, or creep or wriggle slowly over it. Crabs, lobsters, and prawns with long legs and long feelers prowl about hunting for their food; great, many-armed cuttlefishes dart hither and thither, and fishes with gaping mouths and cruel-looking teeth swim very leisurely, for their bones are spongy and their muscles soft, perhaps because in these still waters there has never been any need for great exertion.

Life is most abundant at a depth of about 2000 fathoms, and it varies in richness according to the character of the ooze. But no locality and no depth has yet been discovered which does not harbour living animals of some kind.

Verily, if modern scientific research has deprived us of our mermaidens and our sea-king's palaces, it has given us no unfair exchange in revealing to us this eerie, cold, dark, still world below the waters.

Not the least of our gains is this, the demonstration that there are no slums in Nature. In these inaccessible haunts, in this world of darkness, there is the same order, the same fitness, the same finished perfection, the same

beauty that we find elsewhere. As William Watson has well said:

> "Nay, what is nature's
> Self, but an endless
> Strife towards music,
> Euphony, rhyme?
>
> Trees in their blooming,
> Tides in their flowing,
> Stars in their circling,
> Tremble with song.
>
> God on His throne is
> Eldest of poets;
> Unto His measures
> Moveth the whole."

CHAPTER IV

THE FRESH WATERS

Variety of the Fresh Waters—Similar Animals in widely separated Places—From Salt Water to Fresh—Origin of Fresh-water Animals—Circulation of Matter in the Fresh Waters—The Web of Life in the Fresh Waters—The Danger of Drought—The Danger of Frost—The Danger of Flood—Parental Care among Fresh-water Animals—The Story of the Eel—The Story of the Salmon—The Story of the Lamprey—Water Insects—The Story of the Fresh-water Spider.

THE fresh waters do not occupy even a hundredth part of the earth's surface—1,800,000 square miles out of the 197,000,000, which form the total. But the haunt makes up for its relatively small size by its great variety.

VARIETY OF THE FRESH WATERS

There are lakes so vast that their depths may be as cold, and dark, and plantless as those of the sea itself. Lake Baikal in Asia has a depth of 760 fathoms, with an additional atmosphere

of pressure for every 5 fathoms, and there are seals in its waters. There are shallow ponds of all sizes which vary greatly in temperature from day to night, and from season to season. They may bear a foot of ice in the depths of winter, and be dried up altogether in the heat of summer. Yet year after year these shallow ponds show an abundance of life. It may be noticed that the strict difference between a pond and a lake is not in size, for a pond may be a mile long, but in depth, for a true pond is always shallow. Then there are the lonely mountain tarns with their dark, mysterious waters and a rather sparse animal population; there are great rivers and purling brooks, swift torrents and sluggish streams with little fall; there are marshes grading into the shore, and others passing insensibly into dry land. There are also artificial fresh waters, as in canal and quarryhole. There is a considerable fauna in the water-supply of some cities.

SIMILAR ANIMALS IN WIDELY SEPARATED PLACES

A striking feature about the fresh-water animals is that they are often the same or nearly

the same in widely separated basins. A lake in the Scottish Highlands, one of the thousand lakes of Finland, a lake in Japan, may have similar tenants. Why is this? It is partly because water-birds carry the same small animals on their feet, or in clodlets on their feet, from one lakeside to another, because the wind sometimes does the same, and because changes in the surface-relief of the earth's crust not only make valleys separate from one another, but bring them together again. But the most important reason is probably that the animals which colonised the fresh waters came for the most part from the shore, and that only certain kinds of constitution could stand the change. Let us think for a little what the change from the shore to the fresh waters would mean, always bearing in mind that it would be a very slow and not a sudden change, for most salt-water animals die immediately if they are put into fresh water.

FROM SALT WATER TO FRESH

What characters or qualifications were necessary before the transition from salt water to fresh water could be even attempted?

The first and most important of these was the power to endure slight changes in the degree of saltness. This power would be found most frequently in animals that lived in the shore area, for there such changes occur very often. Heavy rain falling into the smaller pools may make them comparatively fresh, and will also affect the shallow water of the sea itself, though not to the same degree. About the mouths of streams and rivers, too, the water is fresher than elsewhere, and the tides carry up so much salt water that the estuaries are salt, or at least brackish, for a long way up, and only very gradually become quite fresh.

It was, therefore, probably by this route that the rivers and lakes got a great part of their inhabitants. We can easily picture some of the more adventurous of the shore animals making their way slowly up the river mouths until—not in a single lifetime, let us remember, but in the course of many generations—they got beyond the influence of the tide altogether, and settled down in fresh water.

The move seems to have been so successful, in some cases at least, that the enterprising colonists increased abundantly, and some of

them have survived even though all their nearest relatives in the sea have disappeared.

Others again, after long, long ages, seem never to have become quite at home in fresh water, but have to go back periodically to their original home in the sea to deposit their eggs, so that the change from salt water to fresh has to be made by every individual in its own lifetime. The eel is one of these, and its life-story is so interesting that we shall follow it in detail later on.

Another qualification necessary for migrating up the rivers was one which nearly all fresh-water animals must possess—the power of enduring considerable changes of temperature. This power, too, would most frequently be found among the shore animals, for, as we have seen, those living in the open sea have only to sink beneath the surface to protect themselves from sudden changes, while in the deep sea the temperature remains always about the same.

ORIGIN OF FRESH-WATER ANIMALS

But there is a previous question: Why do we think that fresh-water animals must have come from the sea? May they not have begun

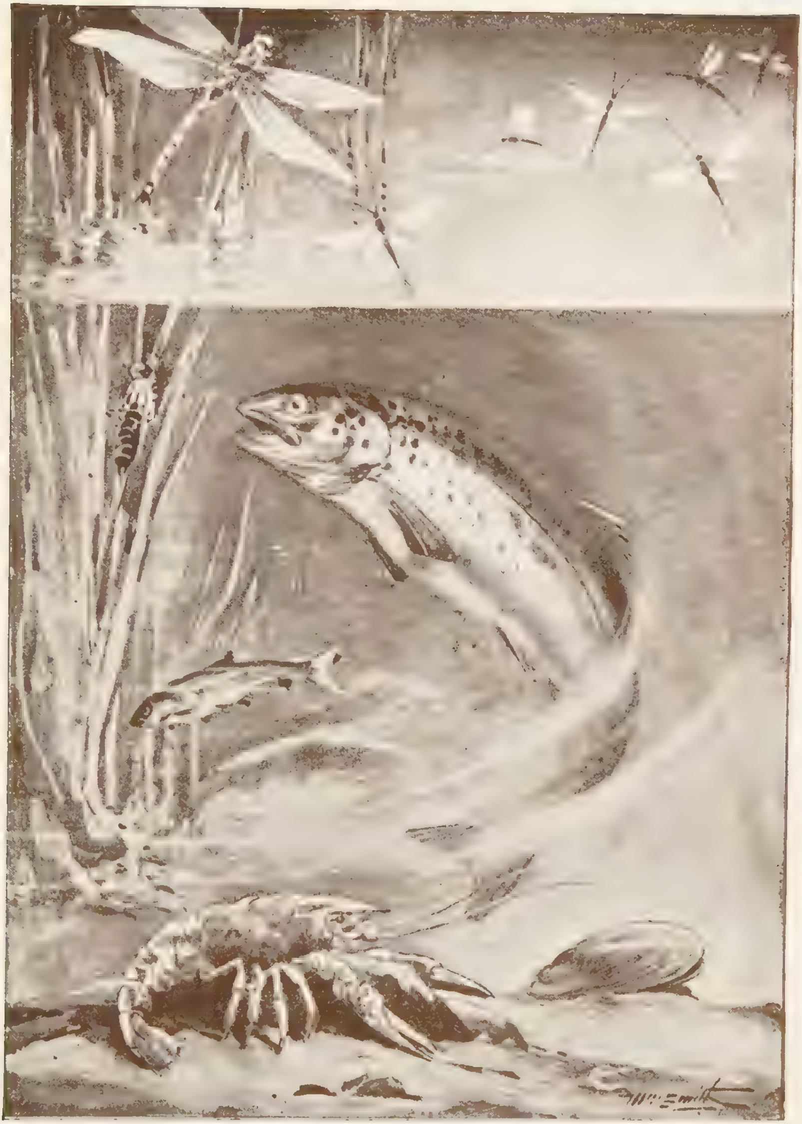


PLATE IX.—A FRESH-WATER POOL.

Showing Trout, Minnow, Crayfish, Fresh-Water Mussel, a little Crustacean called Gammarus, a young Dragon-fly creeping on the reeds, Adult Dragon-fly, and Mayflies in the air.

to be where they are now? To answer this very reasonable question briefly is not possible, but part of the answer may be given. Among the first animals to have bodies—namely, the Sponges—we find one family in the fresh waters, and all the rest—including many hundreds of different kinds—in the sea. That is a straw which shows how the wind blew. Among the Stinging Animals which come next in order—the sea-anemones and corals, the jelly-fishes and zoophytes—only about half a dozen are found in the fresh waters; all the rest—thousands of different kinds—live in the sea. So in many other cases, and the home of the great majority of any great race of animals is likely to be the original home of the race.

Another step in the argument is the Natural History rule that when an animal has more than one habitat in the course of its life-history, the one in which it starts another generation, or begins its own life, is *usually* the original home.

The robber-crab wanders far from the shore and even climbs the hills, but it goes back to the seashore every year to spawn, and there is no doubt at all that it was originally a shore animal. So the fresh-water eel goes to the deep sea to spawn, and there is almost no doubt that

its ancestors were deep-water fishes. Similarly, though the flounder is often found in rivers 20 miles from the sea, it does not spawn in fresh water, it must go back to its old home in the shallow sea. It will be interesting to think out some cases that seem to break this rule.

It is also to be remembered that some animals are at present making the transition from salt water to fresh. The flounder is a case in point, undoubtedly a marine fish, but becoming more and more accustomed to the rivers. The quaint Manatee, included with the Dugong in the small order of mammals, known as sea-cows, or Sirenia, is typically a coastal mammal, but it goes far up the rivers, and it is now found, for instance, in the Everglades of Florida, a far cry from the sea.

In any case we should not think of the fresh-water fauna as a fixed and finished assemblage of animals. It is a noteworthy fact that many fresh-water animals spend only a part of their lives in the fresh water. Some of these seem to be still in process of accustoming themselves to it, others to be leaving it for salt water, and others again are apparently on the way to becoming land animals.

How can we tell in which direction a par-

ticular form is tending—whether it is becoming more of a fresh-water animal or less? The process of change in an animal race may go on so very slowly that at a given point we cannot detect it at all. But that is not to say that it is not taking place. It has been said that if a clock could be invented that would go so slowly that it would only tick once in thirty years, we should not believe that it was going at all. Yet even that rate is fast compared with the rate at which Nature works out some of her wonderful changes.

But though we may not hope to detect Nature actually at work, there are various ways by which those who study her closely can trace out some of the changes that have taken, and are still taking, place. One of these is by comparing one kind of animal with another closely related to it, and trying to make out the meaning of the differences between them. Sometimes so many kinds of animals, with only slight differences between each kind, are found that they can be arranged in a regular series, and it is possible to be fairly certain of the path along which the race has travelled.

Another way is by studying the growth of a particular animal from the time that it be-

gins to form within the egg. For every animal in its early life tends in a greater or less degree to repeat in its personal history some of the stages that have been gone through in the history of its race, and much of this can be made out by a careful study of the stages that appear, often to disappear again very quickly, in the earlier period of the building up of the body of the individual.

The same thing is true to some extent of habits, and, in particular, many animals have an impulse to go back at the breeding-season to bring forth their young in the place where they themselves first began life. Therefore, when we find an animal leaving the haunt in which the greater part of its life is passed, to bring forth its young in quite a different one, we have good grounds for believing that its ancestors once had their home in the haunt to which it returns.

But there is a difficulty here which must be faced. There are some cases in which the youthful stages are passed in a haunt which was certainly *not* the original headquarters. A good illustration of this may be found in insects like May-flies and Dragon-flies, Caddis-flies and Alder-flies, Gnats and Harlequin-

flies, whose larvæ live in the fresh waters. But no one can suppose that these insects, or any insects, had their original home in water. The explanation is that when an animal lives in a haunt full of dangers for the young, it has often circumvented the difficulty by finding another haunt for the juvenile stages. The aquatic larvæ of insects are not old fashioned; they show new-fashioned fitnesses to a haunt which is really rather foreign to the insect's nature.

CIRCULATION OF MATTER IN THE FRESH WATERS

To understand the animal life of a lake or pond we must as usual start with the plants. For the plants, which are able to feed upon the not-living, supply food for the animals which feed upon the living, or what has been living, or what has been made by something living. There are many fresh-water plants growing round the margin, like bog-bean, mare's tail, iris, and bullrush; others, like water-lilies, are rooted at a considerable depth, and send their leaves and flowers on long stalks up to the surface; others, like duck-weed, with roots, and bladderwort, without

roots, float freely. Now there are animals that browse on these plants, and other animals that thrive on the broken-down fragments of these plants, when they decay. But important as these big plants are, they are not so fundamental as the immense number of simple plants that float in the surface-waters—the

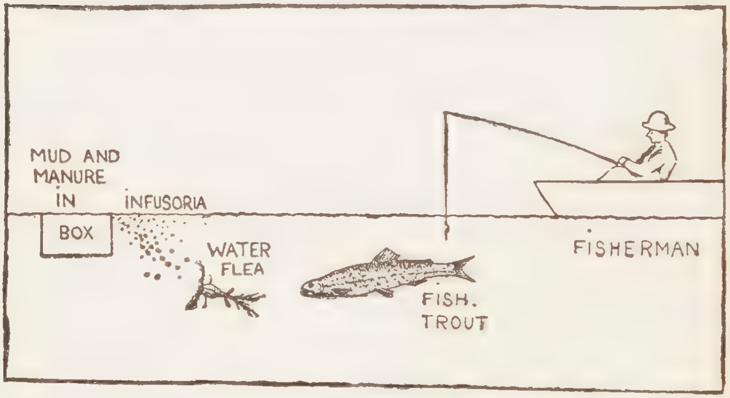


FIG. 13.—BLACKBOARD DRAWING OF CIRCULATION OF MATTER.

Bacteria break down the Mud and Manure; the results and the Bacteria are eaten by Infusorians; these are devoured by Water-fleas, and these by Fishes, and a higher incarnation is in Man.

fresh-water Algæ. These often make the water like green soup; and there are often far more of them in a pitcher than we can see of stars on a frosty night. It is on them that the economy of the pond or lake mainly depends.

These minute plants are the chief *producers* in the fresh-water community. The animals are the *consumers,* though many of them devour their smaller neighbours, who might therefore rank among the producers. When an animal dies in the water, the Bacteria which cause all rotting break down its body into salts and gases. The salts, sooner or later, often with the help of other Bacteria, become the food of aquatic plants, and the gases pass into the air or are captured in the water before they get so far. Thus the Bacteria are the *middlemen.*

The experiment has been made of putting mud and manure in boxes round the edge of a fish-pond, which tended to "give out" periodically, apparently because the water was too sparsely peopled. Bacteria worked at the material in the boxes and made it available for the microscopic animals, called Infusorians, which always abound where there is rotting organic matter. The Infusorians devoured what the Bacteria prepared, and some of them devoured the Bacteria too. A living cataract of Infusorians fell into the pond and formed the food of water-fleas or Copepods, which in turn were eaten by fishes. What was

part and parcel of the mud and manure became, through the middlemen Bacteria, part and parcel of the Infusorians. These were incorporated in water-fleas, which, in turn, found a new incarnation in fishes. What was part and parcel of the fish became part and parcel of man. And so the world goes round. If we believe that fish-food is good for the brain, as some doctors tell us, we may trace the links of a chain between mud and clear thinking.

The sturdy fern, called Bracken, is doing much harm in Britain and other countries by destroying pasture land. It kills out the grass and other useful plants, and it is so vigorous that it can conquer even the heather. One wishes, therefore, that there might be a wholesale repetition of the experiment of tumbling cartloads of bracken into fresh-water lochs. The result, where it was tried, was the great improvement of the fishing. For the bracken tumbled into the water was acted on by Bacteria, and rotted, providing food for Infusorians, which in turn gave sustenance to water-fleas, as these to fishes. If we cast bracken on the waters, we may get, after many days—not bread exactly, but trout!

THE WEB OF LIFE IN THE FRESH WATERS

Nowhere do we find better examples of the web of life than in the fresh waters, meaning by the web of life the linkages between living creatures, binding them together. Here are some examples.

The eggs of the common salt-water mussel are wafted out into the sea and develop into free-swimming larvæ, which eventually settle down; but the eggs of the fresh-water mussel are retained inside the shell and develop in a special brood-chamber, the cavity of the basket-work-like outer gill. They develop into tiny pinhead-like larvæ, called Glochidia, each with two valves toothed at the margin. The eggs are produced about midsummer in Britain, but the Glochidia are not allowed to escape till early in the following year. They are not allowed to escape unless a fish, such as a minnow, comes swimming slowly past. Then the mother-mussel allows some of her offspring to escape, and they come crowding out, like boys set free from school, clapping their valves in the water and exuding delicate gluey threads. Some of them are lucky enough to get attached to the

skin of the minnow; the others perish. The Glochidia are somehow attuned to answer back to minnow, and if we have some in a soup-plate they become greatly excited if a little piece of dead minnow is dropped into their midst. In some North American fresh-water mussels it is to one kind of fish, and to that alone, that the larvæ respond. So subtly interlaced are the threads of the web of life. But returning to our own rivers and ponds, we find that the Glochidia remain for a considerable time on their bearer, the minnow, burrowing a little way into the flesh, and undergoing a great change in the architecture of their body. When the great change or metamorphosis is accomplished, they drop off into the mud and start an independent life as young fresh-water mussels, often far from the place where they were born. We understand then that the fresh-water mussel cannot continue its race unless there is this strange linkage with a minnow.

And just as the mussel is linked to a fish, so there is a fish which is linked to the mussel. For the Bitterling, *Rhodeus amarus,* which lives in some continental rivers, has a long egg-laying tube with which the eggs are actually injected into the fresh-water mussel.

The eggs develop in the gill-chamber, and the larval fishes spend some time there before they find their way out.

Another linkage of the fresh-water mussel is in connection with pearls, for some of the pearls are due to the larval stages of parasitic worms—allied to the liver-flukes—the adults of which live inside aquatic birds. When the microscopic parasite settles down in the skin-fold or mantle of the mussel, it is smothered in layer after layer of translucent lime, mingled with a little organic matter, and the result is—a pearl.

The pied-wagtail, so often seen curtseying on the stones by the side of the stream, is linked to successful sheep-farming, for it is very fond of the little water-snail (*Limnæa truncatula*) which harbours the juvenile stages of liver-fluke, which often causes fatal liver-rot in sheep.

Some authorities say that the decline of Greece was partly due to the introduction of malaria. If this be so, we may link the decline of Greece to the mosquito which harbours and spreads the microscopic animal that causes malaria in man. The malaria-organism, Plasmodium by name, is imbibed along with the blood when the mosquito bites a malaria patient; it goes through complicated changes

FIG. 14.—LIFE-HISTORY OF GNAT OR MOSQUITO.

1. Raft of Eggs. 2. Newly hatched Larvæ. 3 and 4. Larger Larvæ breathing by the Tail-trumpet at the Surface. 5 and 6. Pupæ, with Breathing-tubes on Head. 7. Winged Insect emerging from Pupa-case and flying away.

within the mosquito and multiplies there; when the mosquito bites another man it infects him with the malaria germs of which it is the carrier. Pouring a little paraffin on stagnant pools so alters the nature of the surface film that the larval mosquito, which lives in the water, can no longer hold on to it with its breathing-tube, and dies for lack of oxygen. Moreover, as there are little fishes that greedily devour the larvæ of mosquitoes, and are very useful in water-tanks where the use of paraffin is impossible, we may actually link little fishes to the decline of Greece. "Ye gods and little fishes!"

THE DANGER OF DROUGHT

Life in fresh waters has its peculiar difficulties, and the three greatest are: DROUGHT, FROST, and FLOODS. Especially in warm countries is there great risk of the pool drying up. Little wonder then that many fresh-water animals have learned to lie low in a state of latent life. Some small crustaceans have been known to lie for forty years in dried mud, without losing the power of actively living when the mud was moistened again. A naturalist visiting Jerusalem took a little mud from the pool

of Gihon, at the Jaffa Gate, and put it in a pill-box. It lay dry for forty years, but, when some of the dry dust was then put into a saucer full of water, it gave rise after a short time to some lively water-fleas. Their resting-eggs had retained their vitality for longer than an average human lifetime. This explains why pools, which have been dry for several years, are found teeming with little creatures soon after they have been once more filled with water. The power of lying low in the mud also helps us to understand what we considered already, that similar fresh-water animals often occur in widely separated basins. For mud may be transported for long distances in various ways, *e.g.* on the coats of cattle, and on the feet of birds. When the caked mud is dissolved off in the water, the minute animals may become lively again, or sometimes it seems to be their well-protected eggs that have survived.

In tropical Africa there is a strange fish which has lungs as well as gills. It is known as the "mud-fish" because, when the water of the lake in which it lives gets very low, it burrows down into the mud, and works itself round and round until it has formed a complete mud-casing round its body. This dries

and hardens, and the fish lies safely within it until the rainy season comes, and the lake is once more filled with water. Specimens have been brought to this country within their mud-nests, and they sometimes come out all right, even after they have been out of the water for nine months. A fish out of water indeed!

FIG. 15.—THE QUEENSLAND MUD-FISH (NEOCERATODUS). Breathing by Lungs as well as by Gills.

THE DANGER OF FROST

In many parts of the world one of the severest trials of life is the freezing of the water. Even a resourceful animal, like an otter, may be starved, because the water is frozen, or it may venture through a hole in the ice and fail to find its way back again. Many small fresh-water animals die altogether in the winter, and only their eggs live on, protected within hard envelopes. The fresh-water sponge on the stones of the river and lake dies away, and in the late autumn it looks as if it were rot-

ten. But it does not wholly die. Pinhead-like clumps of cells, called gemmules, protected within a sphere of beautiful capstan-like spicules of flint are formed throughout the dying body of the sponge, and these rest through the winter and start new sponges in the spring. It is interesting to compare this partial dying with what happens to the floating bladderwort, and to some other water-plants. The bulk of the plant dies, but the end of each shoot, heavily laden with stores of starch, breaks off and sinks to the floor of the lake, rising again, lightened, in spring, to start a new floating plant.

Of great importance for living creatures is a peculiar property of water—almost a unique property. It has its maximum density—that is to say, is most closely packed together—at 4 degrees centigrade. When it cools below this, towards freezing, it *expands*, instead of contracting as almost all other substances do when they pass from a liquid to a solid state. The expansion of the freezing water means that the water at the bottom of the pond rises to the surface as it cools below 4 degrees centigrade, and there forms a protective floating blanket of ice. As more freezing water rises

the blanket of ice thickens, and this tends to prevent the water of the pond from becoming colder and colder and eventually solidifying. For eighty-five days in the year—the winter season—the warmer water of the fresh-water basin is at the bottom; the pool does not become solid ice, except in very rare cases; the fresh-water animals are able to continue year in, year out, and from this many consequences flow.

THE DANGER OF FLOOD

Another great risk—in streams, especially—is that of being washed down to the sea, or carried out into a flood-bed and left high and dry, or in stagnancy. We can understand, then, why many fresh-water animals, such as brook-leeches and insect-larvæ, have gripping organs or suckers which anchor them.

But another method of circumventing the danger of being washed away is to shorten down the juvenile stages of the life-history, when the risks are greatest. It is useful to think of an animal's life-history as a whole—egg, embryo, larva (if there is such a stage), young creature, adolescent animal, full-grown animal, ageing animal, and to think of it as a band,

parts of which are elastic, so that they can be stretched out further or shortened down. Thus some animals have a very long embryo period (like Peripatus), others a very long larval period (like May-flies), others a long childhood (like kittens), others a long maturity (like horses). When it is necessary, a part of the life-curve can be, as it were, stretched out in the course of generations—man is stretching out his youthful period—and another part can be shortened down. Many fresh-water animals have shortened down the riskful juvenile period.

A clear example of what we mean may be found in the fresh-water crayfish. It is as high up the genealogical tree as the lobster, and almost as high up as the crab. But while the shore-crab has a long life-history, sketched in our study of the seashore, with one larval stage after another, the young of the fresh-water crayfish is hatched as a miniature of its parent. It is practically identical with its parents, except that the tips of its claws are bent in, the better for gripping the empty egg-shells which are glued to the swimmerets of the mother. It has no larval stages to pass through; it remains in shelter under its mother's tail until it is able to

PLATE X.—A FRESH-WATER POOL.

Showing on the surface Water-Lilies, Duckweed, some insects (Water-Measurers) gliding on the surface, a Water-Snail gliding back downwards below the surface-film. Below may be seen a Crested Newt, two Water-beetles (Dytiscus), a Water-Spider and her dome-like Web; also a Sponge growing on the bulrush.

fend for itself. Indeed, the young crayfishes that have begun to swim about often seek the shelter of the mother's tail, as chickens the hen's wings. This shortening down of the chapters of the life-history is an adaptation that tends to circumvent some of the dangers of youth.

The time taken to grow up may vary even among the same animals according to the season, and may be very different in two closely related species. There occurs throughout Central Europe a larger cousin of our common newt, known as the "fire-salamander," from the large splashes of orange colour on its black body. It brings forth its young alive, but still surrounded by the egg envelope, which bursts at once, setting free a gill-bearing tadpole. This little creature does not take on the salamander form, or leave the water until it is about three and a half months old. But if the summer is dry, and the water in the pools gets low, the stages are gone through more rapidly, and development may be complete at the end of two months. This salamander is not found at a greater height than 2500 feet. Above that its place is taken by another very similar form without the orange spots, known as the black salamander. This form may

occur up to a height of 9000 feet, where it is above the region of pools and quiet brooks, and no water is available, except the cold, swift mountain streams, in which tadpoles could not live or find food. The black salamander, therefore, does not go through a tadpole stage at all; the young are miniature copies of the parent at birth. Moreover, there are never more than two of them, while the salamander of the plains may produce as

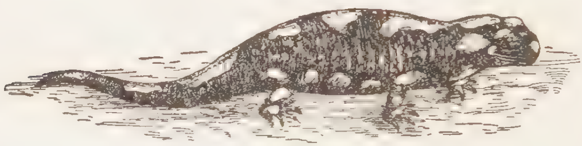


FIG. 16.—THE SPOTTED SALAMANDER (SALAMANDRA MACULOSA). From a Specimen. The Natural Size is about 5 inches.

many as seventy tadpoles in a season. For the pools of the plains are full of hungry little fishes, newts, water-beetles, and their greedy larvæ, and a hundred other carnivorous creatures. So there must be tadpoles enough to ensure that some at least will survive and carry on the race. The mountain salamander, born fully formed, and able, like its parent, to hide among damp leaves and in holes in the ground, has not nearly so many risks to run.

PARENTAL CARE AMONG FRESH-WATER ANIMALS

The common little Bullhead, or Miller's Thumb, has also to take precautions against having its eggs washed away or damaged by running water. This little fish is regarded with some awe by country children, because it apparently utters a cry when it is caught and taken out of the water. But the "cry" is no more produced by vocal organs than is the buzzing of the bee, or the chirping of the grasshopper. The bullhead, in common with a good many other fishes, has the habit of supplementing its gill-breathing by coming to the surface and swallowing a mouthful of air, and it is the sudden rush of this air out of its body that causes the sound. The bullhead lives a solitary life, usually hidden among the stones at the bottom of a rapid stream. It scoops out a nest beneath a stone, to the underside of which it fastens its cluster of eggs. Unlike the lampreys, which show no care for their eggs after they have been deposited, the male bullhead remains on guard over the eggs and young fry for about a month. Then the family breaks up, and the young ones seek

out solitary places in which to hide during the two years that must pass before they become mature, and are ready to look for a mate.

Even more interesting in its habits is the common three-spined stickleback, and, in its case also, it is the father, not the mother, that shows parental care. The male stickleback constructs a barrel-shaped nest of parts of water-weeds, glued together with a sticky substance from its own body. This nest is open at one end, and may be either on the ground or attached to water-plants. When it is ready, the stickleback goes off in search of a mate, and escorts her "with evident pleasure" to the nest. After depositing her eggs, the female fish makes her escape by the simple method of breaking a hole in the nest, usually at the side. Another and another female is brought till the nest is sufficiently full. Then the proud father sets himself to watch over the eggs, keeping them clean, and fiercely driving away all intruders. When the young fry hatch out, his labours are by no means over; indeed, they are more arduous than ever, for he tries to keep his numerous children safely at home as long as possible, but as fast as he drives them in at the front door they wriggle out again at the back!

The stickleback's sharp spines and fighting temper protect him from larger enemies, for even a pike hesitates about swallowing so prickly a creature. But his curiosity is often the undoing of him, for he will snap at the most unlikely bait, even when food is abundant. Their numbers are kept down by man, because of the damage they do in eating the eggs of the trout.

THE STORY OF THE EEL

Although the common eel (*Anguilla vulgaris*) is not wholly a fresh-water animal, it spends most of its life in this haunt, and this is the best place for discussing its extraordinary life-history.

If we are on the look-out beside any of our larger rivers during April and May, we may have the good fortune to see the "eel-fare," as it is called. Thousands upon thousands of tiny "elvers," about 2½ inches long, and the thickness of a bone knitting-needle, are making their way from the sea up the rivers. They keep close to the banks at each side and form an unbroken procession that may take many days to pass a particular spot. They

travel only in sunlight, and a passing cloud will cause them all to disappear like a flash, but when the sun shines out again they swim steadily on their way.

It used to be the custom in some places to catch these little creatures in baskets, to use them for bait, or even to fry them in cakes. But in other places it is realised that this is a short-sighted policy, since the full-grown eels are much more valuable as food. Instead, therefore, of trapping the elvers, people sometimes hang ropes of straw over the rocky places to help them on their way up the river.

From the rivers the elvers push on into the smaller streams and people the ponds and lakes connected with them. If the water or the food-supply in one pond gets low, they have no difficulty in finding another, for, unlike most fishes, they are able to live for a considerable time out of water, and they have a way of wriggling themselves through damp grass for quite considerable distances. One naturalist tells us that he kept two small eels for a time in an aquarium, and "they passed most of the day buried in the sand at the bottom, but night after night they made their escape and were always found in the morning

at the other side of the room, apparently dead; however, when returned to the water they swam about apparently none the worse for their excursion." Once settled down in suitable quarters the elvers begin to feed and to grow, and are now known as "yellow eels." Their food consists at first of worms, larvæ, and small fishes, but as they grow they become very voracious, and will attack water voles and water-fowl, and even larger fishes, among which they do serious damage. There is even a case on record of an eel, 5 feet long, which attacked a swan! The owner saw the swan struggling violently, with its head under water. He went to its assistance and found that its head had been seized by a large eel, which held on so obstinately that it allowed itself to be caught and landed.

About the third summer of an eel's life in fresh water its scales begin to grow. It is an interesting fact that naturalists can tell the age of an eel, or at least the length of time it has spent in fresh water, by examining its scales under the microscope. Each scale is arranged in little zones or rings studded with tiny, limy knobs, separated by narrow rings of smooth material. "This structure is due

to the fact that the eel feeds and grows actively in the summer months only, and the zones are annual rings formed during the summer, whilst the narrow interspaces represent the growth of the scale during the colder months."

After a varying time, usually four to six years in the males, and seven to eight in the females, the yellow eels begin to change to "silver eels." Their eyes grow larger, their pectoral fins longer, and they become silvery-white on the under-side of the body. This is their breeding-dress, and they are putting it on in preparation for the long journey back to the sea.

They have practically ceased to feed by this time, and they make the journey down the rivers in vast numbers, just as they came up. But this time they travel by night, and then only when it is quite dark; bright moonlight, or a flash of artificial light, will send them into hiding at once. During this journey they are caught in great numbers in traps and nets of all kinds, for at this stage they are much valued as food, though in Scotland, for instance, there is a good deal of prejudice against them.

Both the last chapter and the first in the story of the eel's life remain obscure. No one

has yet identified the eggs with certainty, nor the very youngest forms of the fish. Minute fry are now known, however, which grow into 3-inch long transparent larvæ, which feed near the surface of the Atlantic by night, and sink deeper through the day. Some of these "Leptocephalids," which had long been a puzzle to naturalists, were kept in an aquarium, and their gradual transformation to the elver stage was observed. Then many of them were taken at different times from the sea, and it was learnt that towards the end of summer they begin to undergo a change into the "glass-eel," or "transparent elver" stage. At the same time, apparently, they begin their migration towards the shore. The process of changing goes on for many months, and, during that time, they do not feed at all, but live on their own substance. The elver is not only quite different in shape from the earlier form, being now a small eel, but it is fully half an inch shorter.

As to the last chapter, it is supposed that the silver eels from the British Isles go out to the deep waters of the Atlantic and there deposit their eggs, which rise to the surface and float till they hatch. The eels themselves,

like many other animals, probably die after the eggs are safely deposited, for none of them ever reappear at the coasts or in the rivers after spawning.

There are only a few species of eel which enter fresh water; the great majority of the family spend their whole lives in the sea, many of them in deep water. Moreover, some individuals, even of the common eel, do not enter the rivers, but probably remain about the estuaries till it is time to return to deeper water.

On the other hand, some yellow eels do not return to the sea. They may have settled down in ponds which they found it easy to reach when they were little elvers, but difficult to escape from later, or they may lack the impulse to migrate. Such eels may live a long time and grow to a great size, but *they never produce eggs.*

All these facts justify the conclusion that the common eel is descended from ancestors which were entirely sea-fish, and that it has taken to a fresh-water life. Whether it will go farther in the same direction, we have no means of knowing.

We have followed this story at some length,

partly because it is so wonderful in itself, but partly also so that we may get some understanding of the methods by which naturalists interpret for us some of Nature's stories, and of the long and patient labour that is required to determine the facts.

THE STORY OF THE SALMON

Let us now think for a little of another life-story that is in some ways just the opposite of the eels—that of the King of Fishes, the Salmon, which is so valuable as a food, and which is also prized, because its courage and strength make the catching of it good sport.

Salmon ascend most of our larger rivers—if they are clean enough—every year, but not in swarms as the eels do; they continue to go up throughout the spring and summer. Nor are they all of one age and size like the eels. But all of them are impelled by the desire to reach a suitable breeding-place. They are in the finest possible condition when they enter fresh water—fat, with firm, red flesh and silvery skin—for they have been feeding hard and laying up stores of food-material and strength, which have to last them till after the spawn-

ing-time, often many weeks ahead. While in fresh water they feed very little, if at all.

They need all their muscular energy, too, for there are many obstacles to be overcome on their way up the rivers, and the salmon gets his name from his power of leaping. They are said to be able to leap up falls as high as 10 feet, and their courage and persistence in returning again and again to the charge after failure has thus been described: "The lithe body, less silvery than usual, shot out of the water; then followed a plucky rush amid the bubbles; then in seven cases out of ten the fish was swept back before it had cleared the second rung of the ladder. It was as exciting as a race-course. The favourite cleared one barrier after another, lost energy at the last, and was swept back like a log, while another, with less dash about him, cleared every one, and shot ahead in the swift, smooth, sullen water above the fall. There was pathos in the passivity with which the unsuccessful swimmer let himself be swirled back to the eddies at the foot of the ladder. Like a spent horse, he could no more, but one knew that he was setting his teeth, so to speak, for the next rush."

Arrived at the spawning-place—a gravel bed

in a shallow part of the river—the female salmon lashes out a trough with her tail, and in it deposits her eggs, moving gradually up stream as she does so. The attendant male meantime keeps all intruders fiercely at bay. After spawning the salmon are much exhausted, and they linger for a time in the deep pools to recover, but they do not begin to feed actively even then, and many of them die of weakness or disease on their way back to the sea.

The young fry emerge in early spring and, for the first few weeks, remain quietly hidden among the gravel, depending for nourishment on the stores laid up for them in the egg, and now attached to their bodies as a yolk-sac. When the yolk is exhausted, and they are about an inch long, they become more active, and seek for their own food. During all this time both eggs and fry are preyed upon by many enemies, of which the eels, pike, and fish-eating birds probably do most damage. But the young ones that are left, now known as "parr," continue to feed and grow for a couple of years, and then, assuming more silvery hues, descend as "smolts" to the sea. At this stage they are about 6 or 7 inches long, but the abundance of food in the sea, where

they live chiefly on herring, mackerel, etc., makes them grow very rapidly, and those that ascend the rivers as "grilse" the following year are often more than double that length. Many of them, however, spend two or three or more years in the sea before they return, and these grow to a great size. Some do not return at all, but remain about the estuaries. It is unlikely that those that do this ever breed; spawning is only known to take place in fresh water.

THE STORY OF THE LAMPREY

One of the most interesting animals that live in fresh-running water is the lamprey. It is not very easy to see, for most of its life is spent concealed in the sand. But at the breeding season it comes out of its hiding-place, and begins to make preparations for the advent of the next generation.

Let us look for a moment at the lamprey itself. The common brook-lamprey is eel-like in appearance, and, when full grown, is about 7 inches long. Its skeleton is gristly instead of bony, like that of the true fishes. It has two fins on the middle line of the back and a tail-fin, but no paired fins. It has no jaws,

but it has a round sucker-mouth, and a very muscular tongue, covered with horny teeth. With its sucker-mouth it fastens itself to the body of a fish, and, protruding its rough tongue, proceeds to rasp the flesh off its unfortunate victim. Fishes have sometimes been seen to turn over on their sides, so that the troublesome "boarder" is out of water, and is forced to let go its hold.

Along each side of the body of the lamprey, near the head, there are seven conspicuous holes. These are the gill-slits, and the gills to which they lead are continually washed by water. In most fishes, water enters by the mouth and flows out at the gill-slits, carrying away the used air from the blood. But the lamprey uses its mouth to fasten itself to its prey, and, in its case, water flows in at the gill-slits and out again.

The eyes are large, and there is a single nostril, which lies right in the middle line of the head so that, whichever side of the body we look at, we see an eye and eight holes. This is why lampreys are popularly called "nine-eyes" or "niners."

As spawning-time approaches, the lampreys, both male and female, set about preparing a

safe place for the eggs. They choose out a spot with a sandy bottom and, attaching themselves by their sucker-mouths to any stones upon it, they pull these to the lower part of their chosen site, thus making a little dam which will keep the eggs from being washed away. Then they fasten themselves to a stone at the upper edge of their pool, and lash up the sand with their tails, while some of the eggs and sperms are discharged into the water. The eggs sink to the bottom, and the sand settles over them. More stones are added to the wall of the dam, and the laying process is repeated at intervals. Sometimes a number of lampreys combine to make a nest, and they may be seen hanging in a cluster from a stone. When spawning is over, the lampreys are so exhausted that they never recover; they float away downstream and soon die.

The eggs hatch out in about three weeks. The young ones are quite different from their parents, and got their common name of "Prides" long before it was known what they really were. They are yellowish, worm-like creatures, with no visible eyes, and a horseshoe mouth. They make a kind of tunnel open at both ends in the sand, and spend all their time

there, wriggling farther in when disturbed. They take four years to reach their full size, and then, within a few weeks, they undergo the change to the adult form.

The River Lamprey, which is still abundant in the Severn and some other English rivers, grows larger, and usually spends a part of its life in the sea. It used to be considered a table delicacy, and it was from the effects of too hearty a meal of these lampreys that Henry II. is said to have died. They are still caught in considerable numbers, but are chiefly used for bait. There is a still larger Sea Lamprey, that spawns in rivers.

FROM WATER TO LAND

We shall find an instance of animals that seem to be on their way from fresh water to terrestrial life in a very familiar group—the frogs and toads, with their more distant cousins, the newts and salamanders.

We need not go over the life-history of the frogs and toads, because any of us can watch it for ourselves, and it is very much better to see things than to read about them if it is possible. We have only to listen for the croaking of the

frogs in March or April, then look for the clumps of jelly-like eggs, take them home and keep them in a properly shaded vessel, and we can follow the whole fascinating story. But we must be careful to keep water-plants growing in our aquarium, that the water may be aerated, to supply food, but to remove all decaying matter, and to provide a foothold for the little creatures when they are about to make their great change from the tadpole to the frog stage.

All the members of the group have in their full-grown state the great characteristic of adult terrestrial animals—they breathe, by means of lungs, the oxygen in the air. But the young of almost all of them have gills and breathe the oxygen dissolved in water. The time the tadpole breathes by gills may be longer in one family than another, it may even vary in the same family, according to surroundings and weather, but, long or short, it is very rarely omitted.

Another fact that shows the direction in which they are tending is that even the adults are not all equally terrestrial in habit. Both frogs and toads spend some time in the water in spring, and leave it when their eggs are safely deposited. But as winter approaches,

the toad buries itself among withered leaves, or in some dry spot, while the frog returns to the pond or ditch and hides itself in a hole, perhaps in a drain-pipe, it may even be in the damp mud.

But the frog has long ago lost its gills, and its lungs are closed in winter by the shutting of the nostrils. How then does it breathe, for breathe it must, even though the fires of life are very low? The skin is exceedingly thin and delicate, and there is a network of very fine blood-vessels all over it, and the exchange of gases—used carbonic acid gas for fresh oxygen, which is the essential part of breathing—takes place directly from these blood-vessels through the skin.

WATER INSECTS

One more group we must think of for a little—the aquatic insects.

All fully developed insects breathe air through little openings on the surface leading into fine tubes, called tracheæ, which carry the air to all parts of the body. Even insects which spend their whole lives on and in the water breathe in this way. They may

be able to remain under water for considerable periods, because they have various ways of carrying reserves of air, as bubbles entangled among the body-hairs, for instance, while others are able to use the oxygen mixed with the water.

In addition to these, many insects, such as the gnats, may-flies, caddis-flies, and the beautiful big dragon-flies, lay their eggs in the water, and the great changes from egg to larva, from larva to the "resting-stage," which is a preparation for the emergence of the perfect insect, are gone through in the water. Yet this is not a case in which an aquatic race is on the way to terrestrial life; they are not water-breathers, they are air-breathers, which have adopted the habit of laying their eggs in the water for the greater safety of the young. Many of the larvæ have become so well adapted to aquatic life that they are able to breathe dissolved air by gills, but these "tracheal gills," as they are called, are developed from the air-tubes which are present, even though the openings to them are closed. And many of the larvæ breathe surface air from the first. The gnat larvæ, which we may find in any ditch, have a breathing-tube pro-

jecting from the last ring of their bodies, and may be seen hanging head downwards from the surface so that air may enter. There are other aquatic larvæ which *never even get wet.* This is difficult to understand, because it requires a knowledge of physical properties, but it is a fact, and it is illustrated in a very varied way among animals that have gone back from the dry land to the water. Some water-beetles can hardly become wet at all; some keep the greater part of the body dry, but not it all; some become quite wet. The little whirligig beetle (Gyrinus) and the Water Boatmen (Notonecta) become very slightly wetted. The water-spider remains dry over a considerable part of the hairy body.

The time spent in the water is often very long compared with the aerial life. Some of the caddis-flies are said to spend three years in the water, and then only to live a few days. And some aerial lives are shorter still. Some of the May-flies or Ephemeridæ, as they are called, from the shortness of their lives, live only a few hours as winged insects in the air. But their larval life in the water lasts for two or three years, during which they feed, grow, and cast their husk many times. At length

there is the making of the wings and the eventful emergence from the water. They cannot fly much at first, for they are encumbered by a thin veil too truly suggestive of a shroud. They rest rather wearily on the branches of the willows, and on our clothes, as we watch

Fig. 17.—Garden Spider (Epeira diadema).

them. We see them writhe and jerk, till at length their last encumbrance, their "ghost," as some entomologists have called it, is thrown off. Then the short aerial life begins; they swing to and fro as in a dance; they dimple the

smooth surface of the water with a touch into smiling; we see them chasing, embracing, separating. There is great beauty in their film-like wings, in their large, lustrous eyes, in the graceful sweep of the long tail-filaments.

"They never pause to eat; they could not if they would. Hunger is past, love is just begun, and in the near future is death. The evening shadows grow longer—the shadow of death is over the Ephemerides. The trout jump at them, a few raindrops thin the throng, the stream bears others away. The mothers lay their eggs in the water, and, after doing so, many seem utterly spent, and die forthwith. The eggs, however, are in the water, and the race continues."

THE STORY OF THE FRESH-WATER SPIDER

Before we leave the fresh waters, let us look at the water-spider (*Argyroneta natans*), one of the conquerors. It strikes the note of adventure which is so characteristic of animals. For while it is a land animal by nature and origin, and breathes dry air, it has learned to live underneath the water. It is the female

Fig. 18.—The Female Fresh-water Spider (Argyroneta natans).
It has made a Diving-bell-like Web, buoyed into a Dome with Air.
Note Air entangled on Spider's Body. Note special lines to Surface.

water-spider who is particularly admirable, so we shall henceforth say "she." She spins a flattish web beneath the water, and moors it with silk threads like tent-ropes to stones and weeds. A special line runs up to the surface and is fixed to a floating plant. Up and down this rope the spinner goes many times; at the surface she gets air entangled in the hairs of her body; she climbs down, looking like a drop of quicksilver in the water—the air glistens so; she brushes her hair with her legs, and the air-bubbles are caught underneath the web, which thus becomes buoyed up like a dome or like an anticipation of a diving-bell. After many journeys up and down the web is full of dry air, and there the spider deposits her eggs and rears her young. Sometimes when she is in a hurry she gets into the empty shell of a water-snail and manages, we do not quite know how, to fill it with air brought down from the surface. There are many interesting facts about the water-spider, for instance, how she arranges tags of silk among her hair, which probably help in entangling the air-bubbles. For reasons, rather difficult to explain, she never gets wet. But the big interest is just that this spider found an empty

corner—an empty niche of opportunity—full of difficulties, to be sure, but offering new opportunities of food and safety. How splendidly well has she overcome the difficulties and used the opportunities.

CHAPTER V

THE CONQUEST OF THE DRY LAND

Tell-tale Evidences of Marine Ancestry—Origin of Land Plants—The Three Great Invasions of the Dry Land—New Ways of Breathing—Changes in Movements—New Ways of Looking after the Young—New Kinds of Protection — Betwixt-and-Between Animals — Haunts within Haunts—Beneath the Ground—Cave Animals—Arboreal Life.

OVER and over again in the history of animal life some adventurous members of aquatic races have become colonists of the dry land. Perhaps we should not be quite wrong if we said, a little fancifully, that one of the great unspoken wishes of animals was to get out of the water. In any case, it is almost certain that the great majority of the different classes of land animals had their ancestry in the sea, some of them making the transition—which might require millions of years—through fresh waters.

We must be careful here to see the facts clearly. Land mammals had their origin in

land reptiles, and birds had their origin in land reptiles—where then is the marine ancestry? But the reptiles sprang from an ancient amphibian stock, whose very name, amphibian, suggests that they lived partly in water and partly on land. And these amphibians sprang from fishes, and the original fishes were in the sea. So that when we say that the ancestors of land animals were marine, we usually mean their *distant* ancestors, belonging perhaps to a much simpler class. On the other hand, when we look at the terrestrial crustaceans, called wood-lice or slaters, which we see running about if we turn over loose stones or strip off loose bark, we may safely say these are the direct descendants of sea-slaters, such as we find to-day among the rocks on the shore.

TELL-TALE EVIDENCES OF MARINE ANCESTRY

It may be asked, however, why land animals may not have begun their existence on land, instead of being derived from distant ancestors in the sea. This is a good question, which requires a longer answer than is possible here. But part of the answer is this.

Land animals carry about in their bodies the tell-tale evidences of a marine, or at least of an aquatic, ancestry. Thus all the embryos of reptiles, birds, and mammals have gill-clefts on the sides of their neck, opening into the pharynx (the beginning of the food-canal, just behind the mouth), and in two or three cases, in reptile and bird, tuft-like traces of the gills themselves have been recently discovered. These gill-clefts are of no use for breathing in reptiles, birds, and mammals; indeed, we cannot say that they are of any use at all, except the first one, which becomes a tube (the Eustachian tube, named after an old anatomist) leading from the ear-passage to the back of the mouth. But these gill-clefts are always present, and they must be regarded as historic relics. As Darwin said, they are like unsounded letters in words, which tell us part of the history of the word. Thus the unsounded *o* in leopard tell us that this animal used to be regarded as a cross between a lion and a tiger (or pard). So there are vestiges in land animals which betray their aquatic ancestry.

In the ear-passage of a mammal there is a drum or tympanum stretched across just a little way below the surface. On this drum the

waves of sound strike; this is the door at which they knock. But the vibrations have to be conveyed to the real ear—the delicate organ of hearing—which is safely lodged in very dense bone (periotic) deeper down in the skull. Now, running from the drum of the ear to the inner ear, there is, in mammals, a chain of three little bones called the Hammer, the Anvil, and the Stirrup (Malleus, Incus, and Stapes). What do these turn out to be? Their development shows that they are just transformed pieces of bone which, in fishes, form part of the commonplace framework of the jaws. This is another tell-tale evidence of the very distant aquatic ancestry of mammals.

Another very remarkable fact has to do with the blood. Many of the lower animals, such as sponges and jelly-fishes, sea-anemones and corals, and the simpler worms, have no blood; but every one knows that this is very unusual. From ringed worms to man, almost all animals have blood, though, in many cases, like lobster and snail, it is not very noticeable, being practically colourless. This blood is a very complex, chemical mixture; its watery basis contains solutions of salts, sugar, proteins, and nitrogenous waste-products. Every

boy who has put his bleeding finger to his mouth knows that the blood has a salt taste. And it is very remarkable that the salts in the blood are in the main the salts of the sea, and that they occur in very much the same proportions as in the sea. The correspondence becomes closer, when we take into account the change in the composition of the sea since blood was first established millions and millions of years ago. This tells a tale.

We cannot turn back the hands of the world-clock, and get it to strike over again the hours that are past, but there is the rock-record to help us to get away from conjecture. And, as we have just seen, some help is to be got from the individual development which is, in some measure, in the making of organs and the building up of the body, a recapitulation—much condensed and telescoped—of the history of the race.

We should also remember that some of the changes we suppose to have occurred millions of years ago have their counterparts in changes that are taking place to-day. Evolution is not something done with; it is going on. Thus the Robber-Crab is a shore-animal in process of becoming terrestrial.

There is another reason why it is not easy to think of land animals beginning on the dry land; the conditions of life are too difficult for beginners or apprentices. This will become clearer later on, but it may be noticed that breathing and moving, and the disposal of the eggs or young, are much more difficult on land than in the water. As it is much more difficult to escape from enemies when movement is all in one plane, we cannot wonder that many land animals have become burrowers, and other climbers, and others fliers, that others have become camouflaged, and that others have taken to coming out at night only. But we shall return to this subject later on.

ORIGIN OF LAND PLANTS

When we consider the sand-dunes, the rocky islands, the deserts, the mountain-tops, and so on—we feel at once that there are many parts of the dry land which cannot be called very hospitable to living creatures. The dry land is a haunt very much more difficult than the sea or the lake. The fact is that no great colonisation by animals was possible until plants had prepared the way. They provided

food, shelter, and moisture. They were the pioneers for animals, and the simpler plants likewise made higher plants possible.

According to the rock-record, long ages passed before land plants began. For while there are fossil remains of seaweeds in very ancient rocks, there is no definite evidence of land plants till millions and millions of years had passed. It was not till ages after that (early Tertiary) that grass began to cover the earth like a garment—an event with far-reaching consequences.

As to the origin of land plants, there are two theories. It is possible that very simple plants migrated from the sea to the fresh waters, and thence to swampy ground; and that a fresh start was made there which gradually led to a land vegetation. But one of the most thoughtful botanists of to-day, Prof. A. H. Church, has recently argued that the highly developed shore vegetation of seaweeds may have given origin to the dry-land plants by gradual transformation. There is no doubt that the seaweeds have attained great complexity of structure, and it may be that instead of representing a gorgeous blind alley, they point the way to higher plants. If the coast was slowly raised, as it often was,

the great seaweeds might be gradually transformed into terrestrial plants. Who knows?

THE THREE GREAT INVASIONS OF THE DRY LAND

In the conquest of the dry land we can distinguish three great invasions or colonisations. The first was the *Worm-Invasion,* led by simple worms such as the land-planarians, which had begun the profitable habit of moving with one end of the body always in front. In marine animals of comparatively low degree, such as jelly-fishes and swimming-bells, sea-anemones and corals, the symmetry of the body is more or less *radial,* that is to say, there is no right or left, no head- or tail-end. The body can be cut into two almost identical halves along many different planes. Radial symmetry may be illustrated by an orange and by the circular plate it rests on. It is well suited for easy-going life, for drifting in the sea, or for waiting for food to drop into the mouth. But certain worms acquired *bilateral* symmetry, moving with one end of the body always in front. This was better suited for quick and definite movements, such as are

needed in the pursuit of prey or the avoidance of enemies. And as the acquisition of bilateral symmetry was associated with the acquisition of head-brains, we may say that it was the beginning of our knowing our right hand from our left. In any case, radial symmetry is out of the question on dry land, and the first colonisation was attempted by simple bilateral worms.

The most important members of the "worm-invasion" were the earthworms, which probably evolved from a fresh-water stock. This is suggested by earthworms like Alma and Dero, which have gills, and there are many not very distant relatives of earthworms now at home in fresh water, such as Nais and Tubifex, common in streams. The importance of earthworms in the conquest of the dry land is well known, for they have made the fertile soil of the globe. Their successful possession of the subterranean world at an early date implies the previous establishment of some terrestrial vegetation, for earthworms depend for food on the plant remains in the earth, which they swallow, and on such fragments as they are able to capture on the surface.

We know that earthworms have been land animals from very early times, for, though no

actual fossils have been found, as they have no hard parts which could have been preserved, yet we have evidence of the existence of worms in the remote past "by the discovery of the trails which they have left in crawling over soft mud, now hardened into shale or slate, or by the burrows which they made in sand, which has now been converted into sandstone and quartzite. . . ." "Worm-burrows and trails are among the oldest fossils yet discovered."

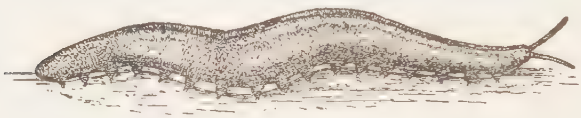


FIG. 19.—PERIPATUS.
A primitive Air-breather, antecedent to Centipedes and the like.

The second great invasion was that of the *Air-Breathing Arthropods,* led by simple jointed-footed animals, well represented by a "living fossil," called Peripatus, an old-fashioned creature, surviving from a very different world. Peripatus is a beautifully coloured soft-bodied animal, worm-like in shape, but with simple stumpy limbs, with antennæ on the head, and two pairs of mouth-parts. It lives chiefly in rotting wood, and comes out only at night. When it is handled it

squirts out from mouth-papillæ tiny jets of slime, and it is believed to do this also as a means of catching small insects. Peripatus is of great interest to naturalists, because in some important respects it resembles a worm, while, in others, especially in the possession of breathing tubes, it has risen to a higher level, and shows relationship with insects. It must be very well adapted to its mode of life, for it is very widespread in warm countries, being found,

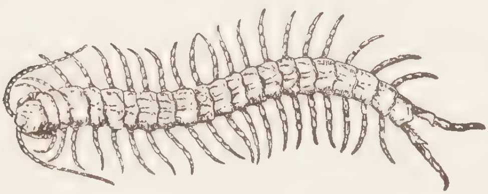


FIG. 20.—A CENTIPEDE.

with slight differences between the species, in Central America, the West Indies, in Chili, in New Zealand and Australia, in Asia, in Central Africa, and at the Cape of Good Hope.

The second great invasion led on to centipedes, millipedes, insects, and spiders, and just as the worm-invasion resulted in the making of fertile soil, so the second invasion had for its great consequence the establishing of a linkage between flowering plants and the

flower-visiting insects, which carry the fertilising golden dust or pollen from blossom to blossom. This is certainly one of the most important linkages in the world.

Darwin's "Cats and Clover" Story.—In his immortal book, *The Origin of Species* (1859), Charles Darwin told the story of the connection between cats and clover—a story that soon went round the world. It is a very familiar story, but it should not become trite to us, for it was the first vivid story of its kind, and it was told by the greatest of all naturalists.

Darwin took one hundred heads of the big purple clover and put muslin bags round them, so that the air and the sunshine could get in, but no humble-bees, which he knew to be the usual visitors of the clover. From these plants he got not a single seed, while from another hundred heads close by, to which the bees had access, he got 27,000 seeds. The fertilising dust or pollen which the bees carry from one clover blossom to another makes the possible seeds into real seeds, that is to say, embryo plants. A nucleus from the pollen-grain, which grows down the pistil of the flower to the ovules, fertilises an egg-cell inside the ovule, and as this develops into an

embryo-plant, the possible seed or ovule becomes a real seed, which will grow into a plant when it is sown. So the more humble-bees, the better next year's clover crop.

But the nests of the humble-bees, which are hidden in the ground or in a mossy bank, are often burglared by the field-mice or voles, which devour the white grubs of the bees. So the more field-mice, the fewer humble-bees.

But the cats on the prowl kill the field-mice, which are therefore scarcer near villages than in the open country. The cats do not appear to eat the field-mice, but they kill them for sport. So the more cats, the fewer field-mice.

One may perhaps go a step further and say: The more kindly ladies in the village, the more cats there will be; and the more cats, the fewer field-mice; and the fewer field-mice, the more humble-bees; and the more humble-bees, the better next year's clover crop.

In any case, we must understand that the pollination or fertilisation of flowers by their insect-visitors, a linkage established after the second great invasion, is one of the most important linkages in the web of life. For the fertilising dust or pollen is necessary if

the possible seeds are to become real seeds which will sprout. And even when the pollen can pass from the stamens of the flower to the pistil of the same flower (self-pollination), the results are not usually so good as when the pollen is carried by insects (or by the wind) from one blossom to another. When there is cross-fertilisation the yield of seeds is better. And the plants so produced tend to be more variable, which will be a good thing if it is useful for the plant to change.

The Third Great Invasion.—It was about the end of the time known as the Devonian or Old Red Sandstone that amphibians made their appearance, and, in the next age, the Carboniferous, when the coal measures were laid down, they had their golden age. These early amphibians, ancestors of our frogs and toads, newts and salamanders, were the advance guard of the third great invasion, which eventually led to the appearance of reptiles, birds, and mammals. This third invasion meant the opening up of many new possibilities for animals, and, in the long run, it led to man.

It is interesting to notice some of the new things that began with amphibians, the ad-

vance guard of the third great invasion. They were the first animals to have fingers and toes (the paired fins of fishes are limbs, but they have no digits), the first animals to have a three-chambered heart (though the mud-fishes come near this), the first animals to have true lungs (though some fishes like the mud-fishes use their swim-bladder to help them in breathing, and it is no doubt the forerunner of a lung), the first animals to have a movable tongue, and the first backboned animals to break the silence of animate nature by having a voice.

Besides the three invasions or colonisations which we have mentioned, there were no doubt others, like that which led to land-crabs and wood-lice (terrestrial crustaceans), or that which led to snails and slugs (terrestrial molluscs).

But in thinking of the conquest of the land, we will not go far wrong if we give prominence to the idea of three great invasions—the first, the worm invasion, leading to the making of fertile soil; the second, the insect invasion, leading to the linkage between flowers and their visitors; the third, the amphibian invasion, leading to the evolution of wits and of love.

NEW WAYS OF BREATHING

The colonisation of the dry land by aquatic animals cannot have been an easy task, and our question now is: What were the necessary qualifications?

The first qualification was ability to capture the oxygen of the dry air. There is a much larger proportion of oxygen in the air than there is mixed with the water, but it is not so readily available. For, mixed with the water, it seems to seep in very readily through the delicate moist skin of the general surface of the body, or of special organs, such as gills. On one side of the membrane there is water, with oxygen mixed in it; on the other side of the membrane there is blood, which usually carries a pigment with a strong affinity for oxygen. What happens in aquatic breathing is that the oxygen diffuses through the skin into the blood, usually entering into a loose, chemical union with the blood-pigment. With its captured oxygen the blood passes to the living tissues of the animal, to the muscles, for instance, and there surrenders its oxygen to keep up the ceaseless burning (or oxidation) which living implies. As the result of the combustion (or

Fig. 21.—Green Lizard (Lacerta viridis). Basking on a Stone.

oxidation) of complex carbon-compounds in the tissues, the waste gas CO_2 (carbonic acid or carbon dioxide) is formed, which is col-

lected by the blood, and got rid of on the skin or on the gills, if there are gills. An animal like a leech is a good example of cutaneous respiration, simply through the skin; a lobworm or a lobster, a mussel or a fish, may illustrate respiration by gills.

But getting on to dry land involved dry skins and protected skins, and the diffusing-in of oxygen was no longer so easy. Thus we find various devices for getting the air into the interior of the body and for spreading out the blood on internal, not external, surfaces. Thus insects evolved air-tubes, carrying fresh air to every hole and corner of the body—surely part of the secret of their great activity—and amphibians evolved lungs, probably transformations of the swim-bladder of fishes.

The lowest animals to show the red-blood-pigment (*hæmoglobin*), which we and all backboned animals have, were certain worms called Ribbon-Worms or Nemertines, which live for the most part on the seashore. The virtue of this hæmoglobin is that it captures oxygen very readily from outside, and parts with it readily to the living tissues, and it is certainly interesting that some of the Ribbon-Worms have become terrestrial. There are many backboneless animals, such as most of the Arthropods and

Molluscs, that have no hæmoglobin, but some other blood-pigment (*e.g.* hæmocyanin) not quite so good. Yet we may be sure that the secret of making hæmoglobin was never lost. It was too good to lose. If hæmoglobin was not always continued along the main line, where hæmocyanin often took its place, it was continued on side-lines of descent; and all backboned animals have red blood. A pretty case, illustrating the value of the red-blood-pigment, is that of the "blood-worms," which are sometimes to be found in rain-water barrels and in stagnant pools, where the oxygen in the water is very scarce. These "blood-worms" are the aquatic larvæ of certain Harlequin-flies (Chironomus); they are called "blood-worms," because they are so red; the redness is due to hæmoglobin, which few insects have; the hæmoglobin is present in "blood-worms," because they live in situations where oxygen is very scarce, where hæmocyanin is hardly good enough. More strictly, perhaps, we should say that Harlequin-flies are insects with red blood, and that this makes it possible for their larvæ to live in very foul water.

The land animals' new way of breathing, notably by means of internal surfaces, like the

breathing chambers of land-snails, where the blood is spread out on the roof of a cavity containing air, or the true lungs of amphibians and higher vertebrates, should be thought of in connection with the fact that land animals tend to become thick-skinned, or to acquire some sort of protection over their skin. An earthworm is still tender-skinned, and it breathes by its skin; a frog is still tender-skinned, and it breathes partly by its skin all through its life, and wholly by its skin in winter. But in the scaly reptiles, in the feathered birds, and in the thick-skinned mammals, usually well-protected besides, all trace of skin-breathing (or cutaneous respiration) has vanished.

CHANGES IN MOVEMENTS

Animals in the water have the great advantage of universal freedom of movement in any direction. They can go up or down, forward or backward, to right or to left, in any and every plane. But land animals can move only in one plane—on the surface of the earth; and this means very great limitations and a great increase of risks. It is more than ever necessary that the movements should be quick and pre-

cise; fumbling and stumbling are fatal. But improvement of movements means a more complicated muscular equipment and a more effective controlling (or nervous) system. It is fair to say that the brain was the controller of movements long before it was a thinking organ.

We do not mean that the movements of aquatic animals are not admirable. The swimming fish or squid cannot be surpassed. We mean that the freedom of movement in the water allows a certain leisureliness (in jellyfishes, for instance) which is impossible on land, unless there is some compensating peculiarity, such as coming out at night. No animal moves at random, but the water animal has a wider range of alternatives than a land animal. And it is not only that land animals are confined to one plane; unless they learn to burrow, or climb, or fly, they have to follow their food with a new strenuousness. In the open sea, the deep sea, and the fresh waters, and, to some extent, on the shore, food is sometimes brought to the hungry animal, but it is very seldom that this can be said to occur on land.

It must be noted, however, that an apprenticeship to quick, precise movements, such as land animals require, was probably served on

the shore, for the conditions of life are more than half terrestrial when the tide is out.

In his fine introduction to Zoology, called *Animal Life,* Professor F. W. Gamble gives a vivid picture of the four chief kinds of animal locomotion. He takes the case of a man in a boat on a river, who can make headway against the current in four ways. (1) He may take a boat-hook and, fastening it to the roots on the bank,

FIG. 22.—A JERBOA.
A leaping Biped belonging to the Rodent Order.

pull himself forward. So does a star-fish pull itself up a rock; so does a leech pull itself forward when it fixes its mouth. This is the *pulling* method. (2) He may take a pole, or an oar for that matter, and, pressing it against the bed of the stream, lever himself forward. So does the beetle push its legs against the ground; so

does the crab on the shore lever itself along; so do we when we walk. This is the *punting* method. (3) He may take an oar, and, going to the stern of the boat, he may press the water from side to side, displacing masses of water in a regular rhythm. So does the fish grip the water with the posterior part of its body, popularly called the tail, and thrust the water away from it, first to one side and then to the other. So does the whale with its propeller-like tail—a propeller, however, that does not go round. This is the *sculling* method. (4) Or the man may sit down on the seat of the boat and take up the oars and row. The insect called the Water-Boatman rows on the water with its third pair of legs; the turtle rows with its flipper-like limbs, and the penguin with its flightless wings and with its feet as well. Aquatic birds, when swimming, row with their feet; some diving birds row under water with their wings. Flying birds row in the air with their wings.

Now it may be said that the conquest of the dry land meant, among other things, that the punting kind of locomotion became very important. It was learned on the shore; it was perfected on dry land. Even the snake, which

is often described as rowing upon the ground with every rib for an oar, is perhaps, more

FIG. 23.—THE AUSTRALIAN COLLARED LIZARD (CHLAMYDOSAURUS).
It is at present trying to be a Biped. When it stands at bay, it expands its Collar. When it runs, it folds its Collar back on its Neck. (After Saville Kent.)

accurately, described as punting with many poles.

Except in the case of some sprawling creatures, like centipedes and snakes, the body of a land animal tends to be compact. The weight has usually to be lifted and supported off the ground, whereas in an aquatic animal the weight is supported in the water. An animal like a jelly-fish is unthinkable on land.

NEW WAYS OF LOOKING AFTER THE YOUNG

The conquest of the land necessarily means new ways of looking after the eggs or the offspring. For the aquatic animal, it is often enough simply to liberate the eggs into the water, which serves as their soft cradle; but it would be fatal in most cases if a land animal merely laid its eggs or its young ones on the ground. They would be dried up or devoured. So we find many ways in which safety is secured, *e.g.* by burying the eggs in underground nests; or by keeping the young ones within the mother's body for a long time before birth, so that they are not very helpless when born; or by carrying them about after birth, as in kangaroos and opossums.

One of the ways of securing the safety of

the eggs or the young ones is to put them all in a hole in the ground. Earthworms make a little barrel of hardened slime secreted by the "saddle" or swollen girdle on their body, and as this slips forward it carries the liberated eggs with it and closes up at the ends. We find it sometimes when digging in the garden. The mother trap-door spider makes a well-finished shaft with smooth walls and a silk-hinged lid, and lays her eggs in a bunch at the foot. The crocodile lays her eggs in the warm earth, sometimes with decaying vegetable matter round about, and the young one calls to her from within the egg when it is ready to be hatched, for it would be awkward to be born 2 feet below the surface. Yet that is what happens to the offspring of those mound-birds that dig a hole in the warm, loose volcanic sand of the beach in Celebes. The mole's nest is also underground —a grass-lined chamber below a big mole-hill.

Another way of securing the safety of the eggs or the offspring is to hide them off the ground altogether. Many insects lay their eggs in or on leaves; many spiders put their eggs in a silken bag or cocoon and fasten this between two leaves, or in a crevice. Some

tree-toads lay their eggs in a damp hole in a tree, and one of them makes a leaf-nest on branches overhanging the water, and arranges matters so that the bottom falls out and lands the contents in the water just as the eggs are turning into tadpoles. The harvest-mouse fastens to the wheat stems its lightly built nest of twined leaves of grass. We must not include the nests of animals like squirrels, which

Fig. 24.—The Australian Duckmole (Ornithorhynchus).
An old-fashioned Mammal that lays two eggs in a well-hidden nest in a Burrow beside a Pool.

have ceased to be terrestrial in the strict sense, or the nests of flying birds and thoroughly aerial insects like wasps.

A third way of securing the safety of the young ones is to keep them for a long time within the shelter of the mother's body, and perhaps to carry them about after they are

born. Thus the old-fashioned Peripatus, which we have already spoken of, carries its young one for a year before it is born. This means that the young Peripatus is able to creep about soon after its birth; it hides itself under the mother's body and, after a while, under bark. Just in the same way among wild horses, which must always be on the move, the foal is carried by its mother eleven months before birth, and the result is that when it is born it is not helpless like a calf (which is hidden in a thicket), but is able very soon to stagger along beside its mother.

Among aquatic animals there is in many cases a long larval life; among terrestrial animals the young are often born as miniature copies of their parents from the first. This is so even when a land animal is quite closely related to one which brings forth its young in the water. We saw that the young mountain-salamander, which has no water stage, because the streams are too swift, is born like its parent, while its near relative, the fire-salamander of the plains, which goes through the early stages of its life in the water, begins as a tadpole, and passes through several changes before attaining the adult form.

With the increasing need for protecting the young there has grown up an increasing degree, not only of parental care, but of parental affection. The highest expression of this is found—if we leave the birds out of account—among the Mammals, that great class which includes forms so different as Man, the monkeys, the carnivores, the hoofed animals, the gnawers, besides the aerial bats and the marine whales. All these animals have one great point of resemblance to which they owe their name of Mammal—the young are fed for the first period of their lives on the milk of the mother. The period of suckling varies greatly in length. The little harvest-mouse, the smallest but one of our four-footed beasts, makes an egg-shaped nest by splitting stalks of grass or corn and weaving them firmly together. The nest, which usually hangs from a corn-stalk, is lined with soft leaves, and in this comfortable home the young ones, eight or nine at a birth, are brought forth, and are suckled by the mother. But she only allows them this luxurious life for a week or two till they are able to see and to stand on their own legs. Then, we are told, she takes them out, "gives them a little practical instruction in the art

of living, and hard-heartedly drives them away." As she will have four or five more litters, all equally large, before the summer is over, we can easily understand that she has not much time to spend over the nursing and education of each set of babies.

In many of the larger mammals the time the young take to develop within the mother and the time of their helplessness after birth are very long, and it is among these that we find parental affection at its best. It is not merely mother-love—the mouse has that, though only for a short time. Both parents show affection for their children, and their common care for them has often led to lasting affection for each other. The lion hunts along with his mate during the breeding-season, but, as soon as she becomes unable to accompany him, he hunts for her, bringing his kill to the den, and letting her satisfy her hunger before he takes his own meal. From the time the cubs are weaned until they are able to hunt for themselves he kills for them too, and when they are able to go out, which is not till they are almost a year old, both parents go with them to teach them their business in life. Both, but especially the lioness, will defend the cubs fiercely from any danger,

and at this stage they are terribly destructive, for they kill anything and everything that they find, whether they need food or not, and this is apparently done to excite the cubs so that they may become mighty hunters in their turn. The cubs remain with their parents till their third year, when they leave the den, but they do not reach their full growth and strength till they are about eight years old.

When parental care grew strong it became unnecessary to have the multitude of offspring produced, for instance, by fishes, which may liberate millions of eggs. For the growth of parental care secured the continuance of the race with comparatively few offspring. But as the number of children decreased it became possible for the mother to know them all, to see more of them, and to have them longer with her, and all this meant more love. And more love meant more care. So things work round in a beautiful circle.

Perhaps this argument may seem very difficult, but it is very important. Let us think it over again. When it became possible for animals to take great care of their children, it also became possible to have quite small families without there being any risk of the race

losing its place in the sun. The cod-fish has its two million eggs, and there is terrific infantile mortality; the golden eagle has usually two eggs at a time, and the eaglets get a good start in life. And when the family was small and the parental care subtle, the parents that were at once good and clever would be most successful. A race with selfish and stupid parents would tend to be wiped out.

New Kinds of Protection.—There is another character which is absolutely necessary to terrestrial life. Land animals must be able to endure, or to accommodate themselves in some way or other, to considerable differences of temperature—between sunlit days and chilly nights, between hot summers and cold winters. We ourselves have this difficulty to face, and we solve it by wearing heavier or lighter clothing, and by heating or shading our houses according to the weather. But we are alone in doing this; Nature has found different answers to the puzzle for others of her children.

A great many animals which find abundant food in summer grow very fat in autumn, and this coat of fat serves as a protection against cold and against scarcity during the severer months. The coats of fur-bearing animals

become longer and thicker at the beginning of winter, and the hairs fall out again in spring. The same kind of animal may have a thicker or a thinner coat according to the temperature of the region in which it lives. The tiger, for instance, is perhaps commonest in the hot jungles of India, but the same species spreads far north to very high-lying and very cold regions, and tigers living in the north have much thicker and longer-haired coats than those in the south.

A very effective way of meeting the dangers of a cold winter after a warm summer is to avoid them by going to sleep. This is called hibernating, and there are many degrees of it. The squirrel, the dormouse, the marmot, and many others fall into a light slumber in their nests beside the heap of nuts and fruits they have laid in, but they wake up and have a meal, and even gather in a few more stores whenever the sun is bright and the day warm.

We may take as an example of the heavy sleepers our common British hedgehog. When winter approaches he chooses a hole in an old wall, or under a hedge, or among tree roots, fills it with withered leaves, buries himself among these, rolls up into a tight ball, and goes

to sleep for the whole winter. He takes no food all that time, but he is not moving, his breathing is very slow, and his heart beats very slowly and feebly, so he is not spending much energy. Life is at a very low ebb, and what waste there is, for there can be no life without some waste, is made good at the expense of the coat of fat he put on in autumn. Not much fresh air gets into his hiding-place, so the carbonic

FIG. 25.—SPINY ANT-EATER (ECHIDNA).
A primitive egg-laying Mammal. The egg is placed in a skin-pocket, where it develops. The Spiny Ant-eater illustrates winter sleep.

acid gas given off by his feeble breathing hangs like a poison cloud all round him and helps to keep him in his heavy stupor. An animal in this state has often been compared to a fire which has been well built and then banked up and allowed to become choked with its own ashes. Hardly any heat is given off, but as long as a red glow remains in the centre of

the heap we can revive the fire by stirring it up to admit air. When we have added fresh fuel and cleared away the ashes it will burn as brightly as ever again. So with the winter sleeper. When the first warm breath of spring penetrates into the hedgehog's hole, he gradually awakens, stretches his stiffened limbs, and creeps forth with a new lease of life. His breathing quickens as his lungs fill with air, oxygen is carried to every part of his body, the heart beats more strongly and rapidly, and the now hungry hedgehog begins to search eagerly for the insects and worms on which he feeds.

If we stir up our resting fire too suddenly and let in too much air at once the glow will die out, and no amount of fresh fuel will re-kindle the heap without fresh fire. Something similar sometimes happens to the lighter sleepers if they have been roused by a spell of mild weather, and a hard frost sets in so suddenly that they are nipped by it before they have had time to settle down to sleep again. But, on the whole, hibernation is a very successful device for withstanding great changes of temperature.

Another way of meeting the winter is by putting on a white dress. The ptarmigan, which is rather grouse-like in summer, with a

suit of grey and brown, puts on a white plumage when the winter sets in; and the chestnut-brown stoat becomes the white ermine—snow-white all over save the black tip of the tail. Now this white dress gives its possessor a garment of invisibility against a background of snow, enabling it to slink upon its victims and to elude its enemies. But there is something more—perhaps more important. For a warm-blooded animal in very cold surroundings the dress that loses least of the precious "animal heat" of the body—the heat that makes it easier for the chemical process of the body to go on—is *a white dress.*

We must not follow this subject further, but it is interesting to think out some of the other ways in which land animals meet the difficulties of the winter. What are the expedients adopted by moles, by harvest-mice, by the mountain hare, by squirrels, by the curlews on the moor, by the slow-worms, by the frogs?

BETWIXT-AND-BETWEEN ANIMALS

Of great interest are the betwixt-and-between animals, at present making the transition between water and dry land. On many tropical

PLATE XI.—SNOW-COVERED MOORLAND IN WINTER.
Showing Ptarmigan and Ermine in winter dress, and Deer in the distance.

shores there is a quaint fish called Periophthalmus, with protruding, very mobile eyes. At low tide it skips about among the rocks, hunting small animals, even catching insects. As it clambers on to the exposed, bent-knee-like roots of the mangrove trees, it may be spoken of as a fish that climbs trees.

There is another tropical fish, known as the Climbing Perch, which has the curious habit of scrambling, by means of its very muscular pectoral fins, up stones, roots, and even the trunks of trees, in search of the insects, grubs, and soft-bodied animals on which it feeds.

Still more surprising is the habit of a South African fish, called Clarias, which is said to make nocturnal raids on the fields in order to eat the grains of millet. This fish lives in districts where the rainy season lasts for only two months in the year. The pools that are filled with rain dry up very quickly in the heat of the sun, and all the rest of the year the fish lives its unfishlike life, hiding in damp burrows through the day, torpid during the very hot season, but in cooler weather coming out on foraging expeditions at night. Some naturalists declare that when this fish is frightened it "screams like an angry cat," but, as no fish

FIG. 26.—PERIOPHTHALMUS. A Tropical Fish that hunts on the Shore.

has true vocal organs, the "scream," like the fainter "cry" of our own bullhead, is probably the sound made by the escape of air from its body. For both Clarias and the Climbing Perch have a special arrangement, a system of tubes branching from the gill-chambers, in which air is stored, so that the fish is not altogether dependent on its gills.

Land-crabs illustrate terrestrial animals in the making. In warm lands, such as Jamaica, there are many kinds, often living in forests far from the sea, sometimes doing great damage in the sugar plantations. But once a year they assemble in enormous numbers to make an excursion to the seashore and deposit their eggs below high-water mark, where they leave them to be swept out to sea by the tide. Then they return, weary and spent, to their inland haunt for the rest of the year.

Darwin, in his *Naturalist's Voyage Round the World,* gives an account of the great Robber-Crab which occurs in the Pacific Islands, wherever the coco-nut palm grows. This crab belongs to the same group as the hermit-crab of the seashore, but it lives in a burrow in the ground, and it lines it with the fibres from the outside of the coco-nut shell.

FIG. 27.—THE ROBBER-CRAB (BIRGUS LATRO).
Notice one climbing up a Coco-palm.

The Robber grows to an enormous size, being sometimes a foot in length, and, as it feeds entirely on the pulp and milk of the coco-nut, its flesh is sweet and oily, so it is regarded as a dainty by the natives of the islands. Darwin believed that the Robber-Crab only picked up the fallen nuts from the ground, though it was known to climb trees, but a later observer has not only seen but photographed it in the act of picking the fruit from the tree. To open the nut "the crab begins by tearing the husk, fibre by fibre, and always beginning from that end under which the three eyeholes are situated; when this is completed the crab commences hammering with its heavy claws on one of the eyeholes till an opening is made. Then, turning round its body, by the aid of its posterior and narrow pair of pincers, it extracts the white albuminous substance."

The Robber-Crab still has small gills, but its gill-chamber is divided into two parts, and the upper part is able to breathe dry air. Yet the Robber-Crab is said to go to the sea at intervals to moisten his gills. The young ones start life in the water very much like young hermit-crabs, but they reach maturity by a less roundabout path.

HAUNTS WITHIN HAUNTS

Until an animal becomes big-brained and resourceful, or is endowed with a rich equipment of inborn gifts which we call instincts, or has some special ways of protecting itself or effacing itself, the surface of the earth is a hazardous home. This makes it easy to understand why there should be haunts within haunts, such as caves and grottos; why some land animals become subterranean burrowers and others arboreal climbers; why some have returned to the water, like the water-beetles and the whales; and why some have sneaked inside other animals.

BENEATH THE GROUND

Among the first animals to discover the world beneath the ground were the earthworms. The strong probability is that they originally belonged to a fresh-water stock, for several earthworms have gills. When they colonised the dry land and became able to breathe dry air through their moist skin, they must have had for a time a Golden Age. Land vegetation had been established, and

they found food enough by eating the soil for the sake of the plant remains in it, and by collecting plant crumbs on the surface. The more they worked, age after age, the more soil they made, and the more plants there were with crumbs to eat. In their newly dis-

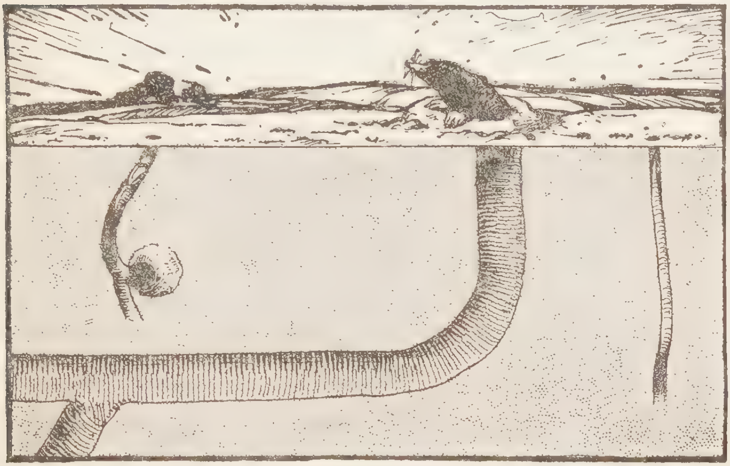


FIG. 28.—DIAGRAM OF SOME BURROWERS.
An Earthworm to the right, a Mole-cricket to the left, a Mole in the middle.

covered country below the ground the earthworms lived, if not in ease, at least in safety. Meanwhile, however, evolution was in progress. The second great invasion of the dry land had occurred, which led on to creatures like centipedes and burrowing, carnivorous

beetles, both of which began to trouble the earthworms in their retreats. Ages and ages passed and the third great invasion occurred, which led on to creatures like burrowing blind-worms, burrowing slow-worms, and, long afterwards, burrowing moles. And so, to cut a long story short, the earthworms which once were so safe, having discovered a new haunt, are among the most persecuted of animals. *So they have become nocturnal.*

When one begins to count up, one finds that the number of subterranean animals is much larger than one at first supposed. Mr. Edmund Blunden had a fine vision of them when he wrote his "Gods of the Earth Beneath" (*The Waggoner, and other Poems,* 1920).

> "I am the god of things that burrow and creep,
> Slow-worms and glow-worms, mould-warps working late
> Emmets and lizards, hollow-haunting toads,
> Adders and effets, ground-wasps ravenous:
> After his kind the weasel does me homage,
> And even surly badger and brown fox
> Are faithful in a thousand things to me."

CAVE ANIMALS

The animals that live below the ground are mostly of a strenuous nature. The mole, for

PLATE XII.—A CAVE IN DALMATIA.

Showing the White Blind Newt (Proteus) in the water, also a Spider and its Web, several insects, *e.g.*, a Cave Grasshopper, a Cave Wood-Louse (a Crustacean).

instance, is one of the strongest of all animals. But it is quite different with most of the animals that have found their home in caves. Many of them are infirm, many are weak-eyed, many are nervous and delicate. While we admit that some of the cave animals may have degenerated because they have lived so long in caves, there is much to be said for the view that most of the cave animals took to the caves because they were weakly. This is borne out by the study of animals that have recently become cave-dwellers.

ARBOREAL LIFE

Animals owe a great deal to plants. In the long run they depend on plants for food; animals use the munitions which plants manufacture. Plants prepared the earth for animals, making it friendly; they helped to secure moisture and soft hiding-places. They formed a subtle sieve against which animal life has often beat, with the best of results. But one of their crowning benefits was in providing animals with trees to climb on. We sometimes use the phrase, "up a tree," to suggest that a man is in a difficult and dangerous

situation, but, as a matter of fact, getting up a tree has often meant a progressive step in the history of animal life. It opens up new possibilities of movement, of feeding, of nesting, and so forth, and it is a portal which many different kinds of animals have tried to enter. Even earthworms have been found up trees, and the land-leeches often drop from the branches. Many insects and spiders are arboreal, and the Robber-Crab climbs the coco-palm for nuts. The skip-jack, Periophthalmus, climbs on the roots of the mangroves, and there are many tree-toads. Among reptiles there are arboreal lizards like the chamæleon, so admirably suited to the branches in having a prehensile tail and both its hands and its feet cleft into two halves for gripping purposes. Then there are green and agile tree-snakes. Many birds and mammals are strictly arboreal, and, in the case of monkeys, the perfecting of the arboreal habit has led to the emancipation of the hand. For when the fore-limb was no longer needed as a supporting member, it became an instrument for touching and grasping, for handling and lifting. And when monkeys got a free hand they also got a nimbler brain.

Plate XIII.—Diagram of Five Haunts of Life.

The Shore of the Sea, with Seaweed; a River, with Fish going up it; the Dry Land, with Stag; the Air, with Dragon-flies, Gulls, and Aeroplane; the Open Sea in the distance, with Steamer.

CHAPTER VI

THE MASTERY OF THE AIR

What Getting into the Air meant—The Flight of Insects—Why are there so many Insects?—The Flying Dragons—The Flight of Birds—Different Kinds of Flying in Birds—Migration the Climax—The Fourth Solution of Flight—Fitnesses of Birds and Bats—Attempts at Flight—Gossamer Spiders.

AGE after age life has been slowly creeping upwards, becoming finer and finer in its forms, and with greater freedom in its ways. And who shall say that this progress is going to stop? In any case the fact is that for millions of years there has been among animals a search after new kingdoms to conquer, sometimes under the spur of necessity, sometimes prompted by a spirit of adventure. So after the open sea and the shore of the sea, the fresh waters and the dry land, we come to the air. The last haunt to be conquered was the air.

Of course there are no animals quite aerial. These dancing May-flies, they spent two or three years as aquatic larvæ on the floor of the

streams. These dragon-flies, whose mastery of the air is almost perfect, had also a long aquatic youth. Perhaps the swift comes nearest a thoroughly aerial creature, for it is on the wing from dawn to dusk, hawking insects without stopping, except to deliver its captures at the nest, never coming to earth at all—there is a note of victory in its shrill cry!

WHAT GETTING INTO THE AIR MEANT

The surface of the earth is a hazardous haunt, but getting into the air spells safety. We see this clearly enough in the chagrin of the cat when the sparrow rises into the air at the last moment, after all the stealthy stalking. It must be very disconcerting to be baulked so neatly. Getting into the air means a return to that universal freedom of movement which animals had in the open water.

It means also getting off the ground often arid and inhospitable, a power of rapid pursuit of moving food, the possibility of quickly passing from scarcity to plenty, or from drought to flowing water. It has led to an annihilation of distance and to a circumventing of the seasons. Last, not least, getting into

the air means new opportunities of reaching suitable places for laying eggs or bringing up the young. The rooks' nests swaying on the tree-tops, what a shrewd idea!

THE FLIGHT OF INSECTS

The problem of flight has been solved four times by animals, and each time in a different way. The first solution was that discovered by insects. In insects the two pairs of wings arise as hollow, flattened sacs, which grow out from the upper part of the sides of the body. They arise from the thorax region behind the head, a region with three rings or segments, each bearing a pair of legs. The wings grow out from the second and third rings of the thorax, and they have nothing to do with limbs. While the wings of a bird are transformed fore-limbs, the wings of insects are on a different line altogether; but we do not know to what they can be compared—they are just insects' wings!

The insect's body is very lightly built, and the secret of the insect's flight is the extremely rapid vibration of the wings, like the propeller of an airship. A watch ticks sixty

times in a minute, but many an insect, such as a humble-bee, vibrates its wings 200 times in a second. In most cases the hum or buzz is simply due to the rapidity with which the wings strike the air, and there is no structure, visible to the naked eye, in the animal kingdom that moves so rapidly as an insect's wing. When the wings are large, as in dragon-flies and big butterflies, the number of strokes in a second is small. There is a fossil dragon-fly whose wings taken together have a span of 2 feet from one side to another, but there is nothing like this to-day.

Insects vary greatly in their power of flight. Many of the two-winged insects cannot fly more than a few hundred yards, and can hardly steer themselves at all, but are borne along by the wind. This is true, for instance, of the mosquitoes, the bite of which in some countries often causes malarial fever. It is true also of our common house-fly, which may cause disease such as typhoid fever, by walking on our food with dirty feet—for it revels in decaying matter, and may come straight from a refuse-heap to our jam-dishes and milk-jugs, carrying with it disease-germs which find there highly favourable conditions for multiplying rapidly.

It is useful for us to know that these insects cannot fly far, for then we can protect ourselves to a great extent by taking care that their breeding-places—stagnant water in the case of the mosquito, manure- and refuse-heaps in the case of the house-fly—are not in the immediate neighbourhood of our dwelling-houses.

But many other insects have great powers of flight. The beautiful, big, rainbow-coloured or sapphire-blue dragon-flies, which are so conspicuous on our moors in sunny weather, fly all day, and sometimes cover two or three miles. They catch their prey of smaller insects on the wing, and can suck the juices from them without ceasing to fly. Their legs have become so weak that they are of no use at all for walking, but are used for perching, and for catching and holding the prey. The bees, too, as we may see for ourselves, are capable of strong and rapid flight, and it has been proved that their daily business of honey-getting may lead them several miles from the hive.

The power of flight in insects sometimes rises to a very high pitch. A wasp has been known to fly tail-foremost for a quarter of an hour in front of a bicycle. Dragon-flies, which

gave some hints to the early makers of aeroplanes, are not only very swift, but have an astonishing power of changing their direction instantaneously. This is well suited for catching other insects on the wing. Another remarkable feature in the flight of dragon-flies is that when they pass from a sunny to a shaded part they often begin at once to practise that mysterious kind of flight called "soaring," so well seen in vultures circling in mid-air; that is to say, they continue moving, but without any visible wing-strokes.

There is no end to the interesting peculiarities of flight in different orders of insects. Bees and their relatives have microscopic hooklets on the front edge of the hind-wings which fix on to a bar on the hind edge of the fore-wings, so that the two wings on each side act as one. In moths and butterflies the same result comes about less perfectly. Beetles spread out their heavy fore-wings—too heavy to be used in striking the air—and clamp them at right angles to the length of the body, so that they serve as vol-planes when the lightly built hind-wings strike the air. In two-winged flies the hind-wings are turned into rapidly quivering "poisers," each like a

stalked half dumb-bell; they seem to be sense-organs, but their meaning is obscure.

In their flight insects are often truly admirable, but it may be noticed that some fly only once in their lifetime, namely, when they are starting a new generation, and that some do not fly at all. The simplest of all insects, the Spring-Tails and Bristle-Tails, seem never to have had wings, a state of affairs to be distinguished from what is seen in fleas, which seem to have lost the wings their ancestors had long ago. The flea, as every one is painfully aware, makes up for its loss of flight by its power of taking extraordinary leaps.

The leaping powers of many insects, such as grasshoppers and crickets, suggest the theory that insects originally used their wings as parachutes in taking skimming leaps along the ground or from branch to branch, before they were able to use them to strike the air as organs of true flight. Just as a creature must walk before it can run, so perhaps the winged insect had to jump and parachute for ages before it could fly, until the muscles of the wings grew strong. The fact that the wings of insects often contain air-tubes and blood-spaces suggests that they originally helped in

respiration, which would raise the pitch of the insect's life.

WHY ARE THERE SO MANY INSECTS?

Many naturalists estimate the number of different kinds of living backboned animals *named and known* at about 25,000. But of named and known backboneless animals there are ten times as many, and the most of these are insects! But some authorities on insects insist that this computation is far too moderate. They point out that, on the average, 6000 new insects are discovered every year, and insist that the total number of different kinds now living on the earth must be put at over 2,000,000. As one of the experts says: "One fact remains certain—namely, that the number of species of insects is at least six times that of all the other animals put together." And besides the prodigious number of different kinds of insects, there is the colossal number of individuals that often represent a particular species at one time. *Why are there so many insects?*

The first part of the answer is that most insects have the power of true flight, which

greatly increases their safety, their chances of getting food, their possibilities of trekking and migrating, and their opportunities—so plain in the wasp's hanging nest—of laying their eggs or nurturing their young ones in places of comparative security, far from the ground, where danger always lurks.

The second part of the answer is that insects have an extraordinarily successful make-up. Thus they have met the difficulty of capturing oxygen by developing a system of branching air-tubes (*tracheæ*), carrying oxygen to every hole and corner of the body. The perfect aeration is part of the secret of the insect's intense activity and success. The blood never becomes impure. Moreover, the beating of the wings helps to drive the used air out, letting fresh air in. Just as in birds, which are also very successful, the flying helps the breathing.

The third reason for the great success of insects is to be found in their remarkable development of *instinctive* behaviour. Along a line which is quite different from intelligence, they have been able to acquire a repertory of ready-made tricks, an inborn ability to do effective things right away without learning.

It has its drawbacks, this instinctive capacity, but it makes for success as long as the unexpected does not happen.

The fourth reason for the surpassing success of insects in the system of animate nature is to be found in their variability or plasticity, linked with that of the plant world. While the fundamentals of an insect's body are always the same, the details vary without end, and this has enabled insects to find an unusual number of *niches of opportunity*, especially in their vital linkages with the likewise very variable, flowering plants. Now, the more niches of opportunity a class of animals can find, the greater will be its success.

A Russian naturalist, Chetverikov, has called attention to a fifth reason for the success of insects. It concerns their skeleton. In backboned animals the skeleton—of living gristle or bone—is *inside* the body; in insects and other jointed-footed (Arthropod) animals the skeleton—of not-living chitin—is *outside* the body. Now it is argued that this entirely different kind of body architecture made it possible for insects to become very minute without ceasing to be very effective. It was more practicable to become small when the

skeleton consisted of external, not-living, durable but elastic chitin, than when it consisted of internal, living, heavy bone. A mouse is a mammoth compared with a midge. Insects were able to fill *minute* niches of opportunity; their insignificance became their strength. Most of the very large insects are extinct; the teeming insect world of to-day consists in the main of small creatures, filling the gaps, as it were, among the higher animals which have evolved on quite different tacks. So we understand better why there are so many insects!

THE FLYING DRAGONS

The second solution of the problem of flight was discovered by the extinct Flying Dragons or Pterodactyls, which flourished in Cretaceous and Jurassic times. They varied from a sparrow's size up to a spread of 18 feet; and their wing was a sheet of skin spread out on the enormously elongated, outermost finger, which is usually reckoned as corresponding to our little finger. They probably clambered about the cliffs, and how far they could fly we do not know. It is not likely

that they were adepts, since the breastbone has only a slight keel for the fixing on of the wing-muscles; and we know that in birds a prominent keel is associated with highly developed flying power, whereas the running birds like the ostrich have no keel at all. On the other hand, the Flying Dragons show, as flying birds do, a solidifying of the middle part of the backbone, giving the wings a firm fulcrum against which to work. It is probably quite safe to say that the Pterodactyls represent a "lost race"; they certainly were not the ancestors of birds. It may be, however, that the *ancestors* of the Pterodactyls and the *ancestors* of our birds were related to one another.

THE FLIGHT OF BIRDS

The third solution was a triumphant one: it gave birds their mastery of the air. There seems no doubt that birds sprang from an extinct stock of Dinosaur reptiles which had become bipeds; and it is highly probable that they were to begin with swift runners that flapped their scaly fore-limbs and took long, skimming leaps along the ground. When

scales were replaced by feathers, no one knows how, the primitive birds probably became arboreal, and served a long apprenticeship as parachutists, launching themselves from tree to tree, until at last they learned to soar aloft.

It is all uncertain, but it is not unreasonable to suppose that before birds became true fliers, they were swift runners of spare build, with light bones, a strong heart, very rich blood, a hot skin, a power of keeping up an almost constant body-temperature, a very good digestion, a fine brain, and the further great advantage that the flapping of the wings, even before true flight was fully attained, helped the breathing. A bird's body is a bundle of fitnesses, well suited for flight, but it is interesting to inquire whether the excellent qualities of birds may not have been acquired *before* they became fliers. But it is difficult to do more than inquire; we cannot roll back the ages and see. We are not even sure whether the Running Birds of to-day (the African Ostrich, the South American Rhea, the Australasian Emu and Cassowary, and the Kiwi of New Zealand) are the descendants of rather primitive birds which never attained to flight, or of flying birds which have lost

their flying powers. Just as whales are the descendants of land mammals which went back to the sea ("secondarily aquatic"), so the Running Birds, with no keel on their breast-bone and no vane in their feathers, may be the descendants of flying birds which went back to the ground ("secondarily terrestrial").

There is a deep difference between the wing of a bird and the wing of a Flying Dragon or the wing of a bat—a deep difference in spite of the fact that all three are transformed fore-limbs. In the Flying Dragon and the bat the wing is what is called a patagial wing or web-wing, for what strikes the air is a drawn-out sheet of skin. But although the bird shows a little patagium or web stretched in front of its wing, the whole secret of the bird's wing is in the feathers, borne by the arm and hand. In a ship the air strikes the sails, in a bird the sails strike the air, and in the bird the sails are the feathers. What made the bird's flight possible was the growth of feathers—feathers with the barbs united together to form a stiff, but elastic, coherent vane which does not let the air through when they press against the air. How feathers began—perhaps it took a million years to per-

fect them—no one knows; but they have the same general nature as scales, and perhaps they may be thought of as glorified scales or parts of scales.

DIFFERENT KINDS OF FLYING IN BIRDS

In the ordinary flight of a bird the wings begin vertically above the back, and every one is familiar with the "clap" that they make in pigeons when they strike one another. They are drawn forwards, downwards, and backwards by the muscles which depress the wing, the largest of which, for it has most work to do, sometimes weighs half the whole weight of the bird. At the end of the downstroke the wing is pulled up again to begin another stroke. To describe a complete movement four adverbs are required—forwards, downwards, backwards, upwards; and the tip of the wing moves through a complex curve, like a figure 8 of which the upper part is much the larger.

A bird is lightly built, but every bird is *heavy,* and if it be killed it falls to the ground with a thud. As Ruskin said, we go quite wrong if we think of a bird as like a buoyant balloon; it is like a flying bullet. In other

words, the bird has to exert itself to keep up in the air. In the stroke of the wing it has to displace—to thrust away from itself downwards and backwards—a mass of air bigger than its own body. The resistance the air offers to being thrust away is what keeps the bird up.

If we watch birds we see that the first strokes of the wings in lifting the body cost them much. A Great Northern Diver cannot rise off the ground at all, though by getting some weigh on by swimming rapidly it can launch itself clean out of the water. We often see a cormorant taking a little run along the rock to get up speed enough to enable it to rise. Even after it has got launched in the air it often strikes the water again and again. Birds like to start from a vantage-point, and a pigeon gets woefully tired if it has to start many times in quick succession from the ground. But note the important point: Ce n'est que le premier pas qui coute; once the bird has got up a certain velocity in the air, the effort required to keep itself up becomes beautifully less. Sir Isaac Newton showed that it decreases in proportion to the square of the velocity, and this is a very important fact. If there is

no wind against the bird and if the bird is not rising, the work of rowing with its wings in the elastic air is not hard. A ship has the advantage that it floats in the water, whereas the bird cannot float in the air; but the ship has the disadvantage that the water offers considerable resistance to a body passing through it, whereas the air offers little resistance to a smooth body passing *quickly* through it.

The second kind of flight is *gliding,* seen when a bird, having got up a certain speed, rests on its oars, and holding its wings taut glides along, or when a bird launches itself from a tree and with outstretched, but unmoving wings, glides to the ground. When a bird glides along after getting up speed it is bound to sink, but this may be counteracted for a time if an ascending current of air beats up against the bird's outstretched wings from below. We often see this when a gull flying from the fields seawards meets just above the edge of the cliffs an ascending landward breeze. In this case there is a transition to the third kind of flight, called "sailing."

SAILING FLIGHT.—When an albatross goes up one side of the ship, keeping pace with the vessel, without a stroke of its wings, we

see a marvellous thing, but the marvel increases when in front of us the bird tilts its body and turns, and comes towards us down the other side of the ship, and all, so far as we can see, without a stroke of its wings. This sailing is, we think, the most wonderful locomotion in the world, and the puzzle of it does not seem to have been altogether solved. It is finely illustrated by vultures "soaring" in mid-air, describing circle after circle, ascending in a magnificent spiral and sailing down again, and all, so far as the field-glass shows, without any stroke of the wings. The word "soaring" is often applied to this mysterious kind of flight, but "sailing" is a better word. It is better to keep "soaring" for the ascending flight of the lark, where there is very rapid up-and-down movement of the wings, without any backward stroke. This leads on to the "hovering" of the kestrel, where the up-and-down movements of the wings are extraordinarily rapid, and to the "fluttering" of a humming-bird, poised like a moth before a flower. But sailing is a different matter.

Sailing is seen in birds with a large wing-area or sail-area in proportion to the size and weight of the rest of the body, *e.g.* albatross,

vulture, gull, raven. It is seen only when there is some breeze, but there may be considerable wind overhead when there is little or none near the ground. For long intervals there are no ordinary strokes of the wings, though it is a bold thing to assert that the wings are not moving at all. It is often associated with a tilting of the body, which can be effected by movements of head and neck, shoulder-joint, and tail. It is not due to massive up-currents of air playing upon the under surface of the bird, for it is sometimes exhibited when light objects like feathers are seen sinking slowly in the air. It is highly probable, however, that the sailing bird takes advantage of horizontal currents of unequal velocity in the air. It is also highly probable that the bird having got up some speed by strong strokes sustains this velocity against the wind *and rises in its sailing;* that it turns and comes down with the wind, getting up, without strokes, sufficient speed to rise again. In other words, it is continually changing "energy of position" into "energy of motion," and conversely.

It is important, we think, to remember one's own experience in such an exercise as skating, that, given a certain speed, slight movements

of the body, to one side or the other, bending and straightening, may be very effective although there is no actual movement of the legs. Experienced mountain-climbers are also aware of the importance of slight adjustments which are eventually made almost without thinking. In any case we are probably safe in saying that the sailing albatross is not behaving like a kite.

MIGRATION THE CLIMAX

The crowning advantage of the power of flight in birds was that it enabled them to migrate, to evade the difficulties of the winter. In north temperate countries the great majority of the birds show this seasonal mass-movement between a nesting-place and a resting-place, the former being always in the colder part of the range. It is remarkable in many ways, this migration of birds (see our *Wonder of Life* (1914) and *Biology of the Seasons* (1911)); it occurs in such a punctual, orderly way; it is such an intense activity, for many migrants seem to keep up for hours on end a speed of a mile a minute; it means such an annihilation of distance, for the Pacific Golden Plovers of

Hawaii seem to think nothing of setting out for Alaska; it means some sense of direction that we do not understand, for a young bird that has never been more than a few miles from home will start gaily in the autumn for tropical Africa and will reach its goal in safety, and, what is more, will sometimes come back again the following spring to the precise place of its birth.

THE FOURTH SOLUTION OF FLIGHT

The fourth solution of the problem of flight was discovered by bats. In its idea it is nearest that of the Flying Dragons, but it is quite independent and by itself. Bats are, of course, true mammals, covered with hair, and giving milk to their offspring. They are most nearly related to the Insectivores, such as shrew and mole, and it is interesting to notice that there is in the Far East an aberrant insectivore called Galeopithecus, placed by some authorities in a special order, which has a sheet of skin stretched between fore- and hind-limbs, and is a very expert parachutist.

The wing of the bat is formed of a fold of skin, which usually begins at the shoulder and

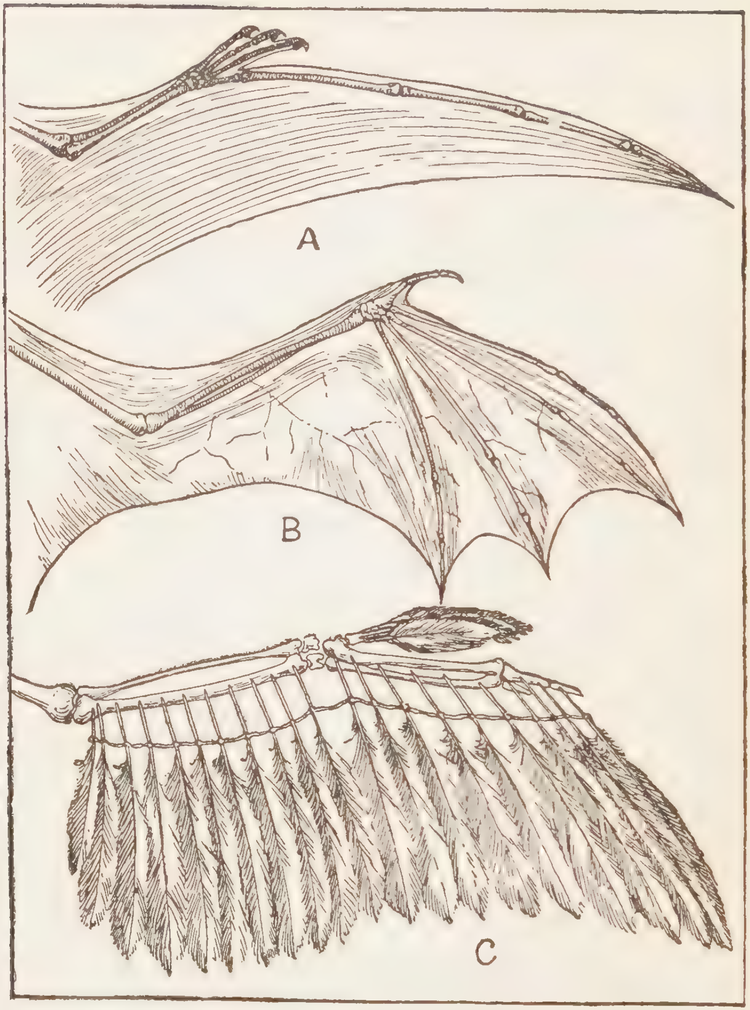


FIG. 29.—WINGS OF DRAGON (A), BAT (B), BIRD (C).

stretches along the upper margin of the arm to the hand. The thumb, which is small and clawed, is left free, but the membrane stretches across all five palm-bones and to the very tips of the four very long outspread fingers, and from them to the legs. The knees are turned outwards and backwards like our elbows, to meet the membrane, which reaches down to the ankles, leaving the feet free, but filling the space between the hind-legs, and including all the tail except its tip. The span of the outstretched wings varies from 2 inches to 5 feet.

This wing membrane is a very wonderful thing. On a dead bat it looks like a piece of dry, tough skin, but it is in reality so well supplied with nerves and blood-vessels that it is exquisitely sensitive. The bat is, in the most literal sense, alive to its finger-tips, for the sense of touch in the whole of its wing is extraordinarily delicate. When it gets into a room, as it often does, for light seems to attract it, it will fly round and round without ever knocking against wall, cornice, or wardrobe, and out of doors will pass in and out among the branches of a tree without coming in contact with them, because of its power of feeling things before it touches them. Its

mouse-like ears, and the curious leaves of skin about its nostrils are also very sensitive, but it scarcely seems to need these to show it what to avoid when flying. Some say that as the bat flies it utters its high-pitched cry, and that the echoes of this from branches and the like help it to avoid obstacles.

On the ground the bat is very clumsy and can only shuffle along, as indeed we should expect from the fact that both fore- and hind-limbs are taken up in the making of the wing.

All the bats in Britain—and there are about fifteen different kinds—belong to the smaller insect-eating section. They remain in retreat by day, but on mild evenings they may often be seen flying about in pursuit of the gnats, flies, and moths on which they feed. The commonest of our bats, which is also the smallest, is known as the pipistrelle. Its body, covered with reddish-brown fur, is only about 1¾ inch in length, but the expanse of wing makes it look much bigger in the air.

As cold weather approaches and insect life gets scarce, the bats retire to winter quarters. A cave, a disused chimney, the roof of a barn, a church tower, a hollow tree—any dark, quiet spot will serve their purpose. Like other

Plate XIV.—Bats flying in the Twilight.

hibernating animals, they have stored up as much nourishment as possible within their bodies before laying themselves up for the winter, and now they hang by their toes with their heads downwards and their wings wrapped about them, sleeping comfortably, though not very profoundly, for a mild spell will wake them up, until spring comes round again. Quaint creatures that hang themselves up by their toes and wrap themselves up in their arms!

The young ones, usually only one at a time, are born in May, and by July they are able to fly with an uncertain fluttering movement that makes them look like big moths in the twilight.

The nature and abundance of their food makes it unnecessary for our British bats to fly very far, but some of the larger fruit-eating bats of warmer countries make enormous daily journeys in search of their favourite fruits. We are told that the "flying fox," so called from the foxlike look of its long, red-furred snout, will fly many miles, and even cross an arm of the sea, when there are orchards to be robbed. The young one attaches itself firmly to its mother's breast, and so can

be carried without impeding her flight. Thus the bats, though belonging to a class nearly all of the members of which live on land, have become thoroughly adapted to aerial life.

In insect-catching bats the skin is continued from the hind-legs to the well-developed tail, and this "inter-femoral membrane" forms a very useful pouch. For when the bat has caught a good-sized insect, such as a night-flying beetle, the difficulty arises of crunching it without letting it go from the grip of the jaws. In her delightful *Wild Animals of Garden and Hedgerow* (1920), Miss Frances Pitt points out that the bat lowers its head to its skin-basket and, pressing its booty against that, can crunch it comfortably without risk of losing what it has gained. During this process, which is quickly over, the bat tumbles a little in the air, but speedily recovers itself.

FITNESSES OF BIRDS AND BATS

Birds and bats are not in any way related to one another, except that the two classes, birds and mammals, may be traced back to a common ancestry in extinct reptiles. It is all the more interesting to find that similar fitnesses or

adaptations for flight have been wrought out in the bodies of bird and bat. Both are lightly built as regards their skeleton, which means a big surface for fastening muscles on to, without great increase in weight. Both show a keel on the breastbone for the better fixing on of the muscles of flight, but the bat's keel is much less prominent than a bird's. Both show a solidifying of the middle region of the backbone, which affords a firm fulcrum for the wings to work against. In almost every other respect they are as different as different could be, but it may be noted that most birds and most bats are small, as if there were a size-limit to flying creatures. A bird like an albatross, with a span of 11 feet from tip to tip of the outstretched wings, is quite out of the common, and so are the very large fox-bats of the Far East.

ATTEMPTS AT FLIGHT

Apart from man, the problem of flight has been successfully solved four times—by insects, Pterodactyls, birds, and bats; but how often has its solution been attempted? It is very interesting to study these attempts, some of them splendid failures.

(*A*) There has been much discussion over the FLYING FISHES, whether they show anything that can be called true flight, that is to say, whether their fore-fins strike the air or not. The general answer, for the common flying fish, *Exocœtus volitans,* which one sees when one crosses the Atlantic, is that the creature takes a great leap out of the water, using its tail as propeller, and helped perhaps by the momentum of a wave; that it holds its pectoral fins taut, without more than slight vibrations, and uses them as vol-planes, not as wings; that it may for mechanical reasons rise in its vol-planing, so that it lands on the deck of a ship; and that the alteration of the curve of movement is in the main involuntary, being due to a slight tilting of the body. We have watched the common flying fishes with care and we never saw anything approaching a stroke with the fore-fins. We have seen them cross in front of the prow of the steamer and, in the course of their curve, come crashing against a port-hole. The leaping is often a desperate attempt to escape from their enemy the tunny.

In regard to the Flying Gurnard (Dactylopterus) some good observers have described a fluttering of the pectoral fins, which looks like

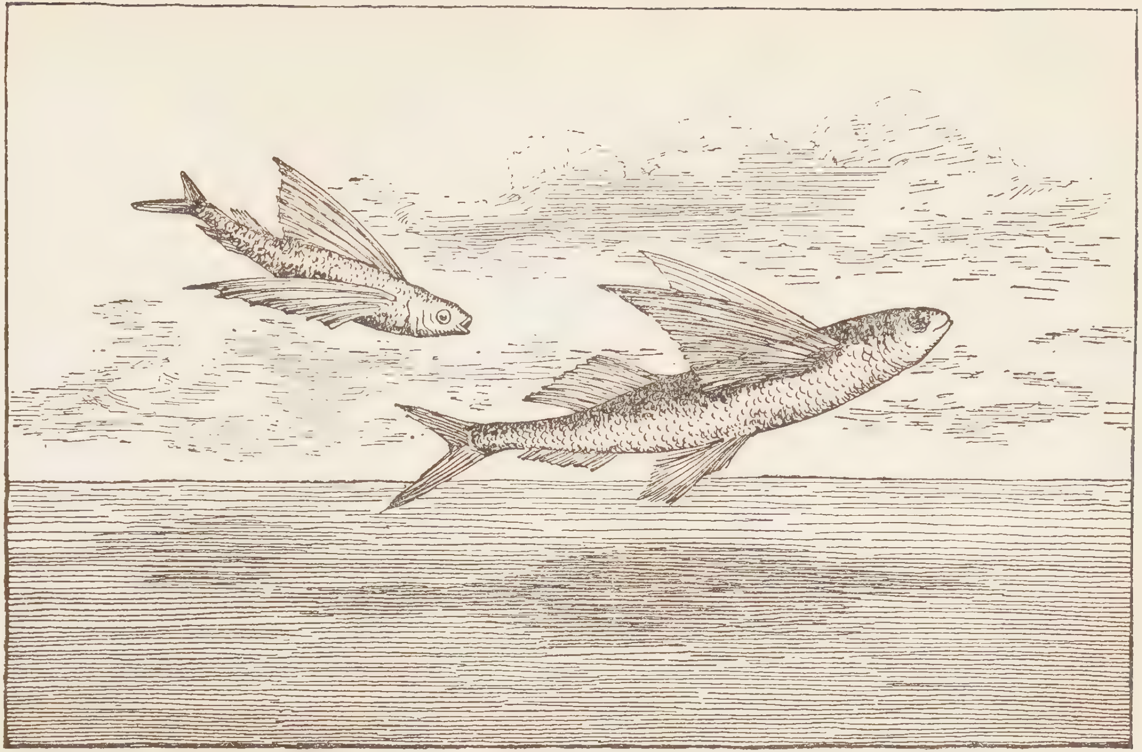


Fig. 30.—A Flying Fish (Exocœtus).
Sometimes leaping high, sometimes utilising a Breeze to "sail" like an Albatross.

the beginning of flight, and there is no reason why this should be called impossible. It has to be remembered, however, that though the muscles of the pectoral fins of flying fishes are larger in proportion than in related fishes, they are not much larger. It follows that there cannot be *much* striking of the air. At the most, there is only a beginning of flying.

Recent studies of flying fishes have shown that the "flight" differs greatly according to the atmospheric conditions. It is short when the air is still; it is long when there is a breeze. In fact the "flight" of flying fishes sometimes approaches the "sailing" of the vulture and the albatross.

(*B*) Another attempt has been made by some tree-toads, which take flying jumps from branch to branch. In our common frog there is a familiar web on the large hind-feet, which is obviously well suited for striking the water in swimming. In the flying tree-toad, Rhacophorus, there is a web between the fingers as well as between the toes, and thus the animal has four parachutes.

(*C*) There is something fascinating in the little Flying Lizard, *Draco volans,* of the Malay States, which has gone far towards

PLATE XV.—FLYING DRAGONS (*Draco volans*) OF THE FAR EAST.

The parachute of skin is spread out on five or six greatly elongated mobile ribs. Note the upper and the under surface. Also how the parachute is closed in when the animal—a Lizard after all—rests on the branch.

FIG. 31.—FLYING TREE-TOAD (RHACOPHORUS).

flight on an idea of its own. Like all other parachutists, except the Flying Fishes, it lives in trees, and it is able to take daring leaps from one to the other. It has five of its ribs much

FIG. 32.—THE LITTLE FLYING DRAGON (DRACO VOLANS) OF MALAY.
Note the Pendent Pouch (P) on its Throat, and the Extended Ribs (R) supporting the Parachute.

elongated and very movable, and they carry out between them a sheet of skin. When the little dragon (Draco, its name) is resting we do not notice much that is peculiar, for the long ribs fold in and lie parallel with the backbone,

like a collapsed umbrella. When it is going to "fly" the ribs are extended and form the supports of a fine parachute. The dragon can swoop several yards, sometimes to avoid an enemy, sometimes after a swarm of insects. The upper surface of the body is brightly coloured, and there is a curious dewlap on the throat.

There is another tree-lizard, Ptychozoon, whose long tail bears a scolloped fringe of skin on each side, and this again helps in swooping. There is a tree-snake (Dendrophis) which disdains all accessories and launches itself stiffly from a lofty branch to the ground. But is there anything in the way of movement a snake cannot do except cross a sheet of ice or a horse-hair rope?

(*D*) What bats achieved many mammals have attempted, that is, if we regard parachuting as on the way towards flight. It is noteworthy that all the attempts at flight among mammals have been made in families that are arboreal in habit, so that climbing tall trees may have been the first step towards acquiring wings or some substitute for them. Thus we have the flying phalangers of New Guinea and Australia, including many species, "the largest of which is as big as a cat, while the smallest

is no bigger than a mouse." All of them live among tall trees and keep hidden in the branches till evening, when they become very active in search of the fruits, leaves, and insects on which they feed. Their flight, too, is of the parachute order, but it is much more effective than that of the flying lizard. They have a fold of skin covered with hair extending from the fore-legs to the hind-legs, and, when they launch themselves into the air from the top of a tree, the outspread skin bears them up for a considerable distance, and even enables them to change their direction a little while in the air. They cannot, however, move the fold of skin up and down, and therefore they can only "fly" to a lower level than they started from.

The "flying squirrels," mostly found in Asia, have a somewhat similar arrangement, and they are able to leap a distance of 20 yards. The curious "flying lemur" or Colugo of the Indian Archipelago has an even more effective parachute, for its fold of skin does not stop at the hind-legs but fills the space between them, the long tail passing down the middle. Mr. Wallace, the naturalist, observed the flying lemurs in their native haunts, and he thus describes their flight: "Once in a

bright twilight I saw one of these animals run up a trunk in a rather open place, and then glide obliquely through the air to another tree on which it alighted near its base, and immediately began to ascend. I paced the distance from one tree to the other, and found it to be not less than seventy yards, and the amount of descent I estimated at not more than thirty or forty feet, or one in five. This, I think, proves that the Colugo must have some power of guiding itself through the air, for otherwise in so long a distance it would have little chance of alighting exactly on the trunk."

An interesting point in regard to these parachuting mammals is that there are so many which seem to be independent of one another. It is worth while making a technical list, because it shows how the same impulse must have become urgent over and over again.

GALEOPITHECUS	Perhaps to be ranked among the Insectivores.
ANOMALURUS PETAURISTA SCIUROPTERUS	Among the rodents, related to squirrels, but differing markedly from one another.
PETAURUS PETAUROIDES AEROBATES	All of them Marsupials, but not nearly related to one another.

THE BALLOONING SPIDERS

In these parachutists, some of which have their faces set towards flying, we get a glimpse of what is certainly a quality of living creatures—the quality of endeavour and experiment, of insurgence and adventure. We cannot get the right word for it, because it is a characteristic of life itself, asserting itself at many levels. We find it among the simple primeval creatures of the Open Sea, which do not form "bodies" in the strict sense, but expend all their endeavour in fashioning their single "cell," so that it is often like a fairy palace, and is a little world of internal microscopic complexity. We find it in the simple sedentary creatures of the shallow water, whether seaweeds or sponges, zoophytes or corals, which add to the self-preservation law of the firstlings, as Dr. Church says, the second great law that no race will continue unless the individual members do their bit in securing its continuance. We find it in the instinctive behaviour of ants and bees, in the instinctive and intelligent behaviour of birds and mammals, in the instinctive, intelligent, and rational behaviour of man.

Plate XVI.—Gulls in Flight.
Photograph by Ratter, Lerwick.

No book nor naturalist can ever come within sight of the end of the study of the haunts of life, but as we must close these studies now, we wish to finish with a picture which may serve as an emblem of the quality of life which seems to us so characteristic. Our picture is that of the Gossamer Spider, a terrestrial creature which makes aerial journeys without wings.

At many seasons of the year, but in the autumn especially, many small spiders of various kinds mount on to gateposts and the rails of wooden bridges and tall plants like ragwort. They stand with their head to the wind, and allow threads of silk—four is a common number—to float out from the spinnerets at the hind end of the body. When these are long enough the wind grips them, and the spider lets go, usually turning upside down. On the wings of the wind, supported by the silken parachutes, the spiders are borne from one parish to another, from a crowded place it may be to a free place, from a hungry land it may be to a land of plenty. Sometimes they are borne in safety over a sheet of water, though the tips of their toes may touch the surface film. If the wind should rise, the ballooning spider can wind in its threads,

FIG. 33.—GOSSAMER SPIDERS.
On their Aerial Journey.

as we see one doing when it reascends the thread by which it has lowered itself half-way from the roof. If the wind should fall, the spider can pay out more thread. It is quaintly like the sailor furling and unfurling his sails. When the spiders feel they have had enough of aerial journeying, they wind in some thread and sink to the ground. When ten thousand little spiders do this about the same time there is what is called a shower of gossamer. The countless threads are seen on the hedgerow and on the ploughed field and on the lea, and if we kneel down and look against the light we see the quivering, glistening maze—an image of the web of life itself. But what impresses us most is the simple fact that a wingless terrestrial creature journeys through the air. It has attempted the apparently impossible and achieved it. We are filled with a reasonable wonder at the adventurousness of life.

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